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editor & publisher
Don Shay

associate editor
Paul Mandell

contributing editors
Jordan Fox
Bill Pearson

editorial consultant
Robert P. Everett

editorial services
Ann Dredla

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Computer Imaging — An Apple for the Dreamsmiths. 4

It is unlikely that any technological breakthrough of the last decade will have as significant a long-term impact on the way motion pictures look and are made than will the burgeoning field of computer generated imagery. From the earliest advances in the art and technique of computer animation to the current state of the art, a solid overview is presented on the past, present and future of computer graphics, digital scene simulation and electronic compositing. *Article by Peter Sprensen.*

Dragonslayer 30

When Hal Barwood and Matthew Robbins set out to make a sword-and-sorcery fantasy, they had no idea it would spawn the most significant innovation in dimensional animation since its inception. ILM dragon-masters Dennis Muren, Phil Tippett and Ken Ralston discuss the development and utilization of "go-motion" animation, aided and abetted by dragon mover engineer Stuart Ziff, optical supervisor Bruce Nicholson, armature builder Tom St. Amand, miniature set builder Dave Carson, matte painting supervisor Alan Maley, makeup artist Chris Walas, and animation supervisor Sam Comstock. Non-ILM involvement is recounted by dragon designer David Bunnett, full-size prop maker Danny Lee, and VCL animation supervisor Peter Kuran. *Article by S.S. Wilson.*

The Wrath of God... and Other Illusions. 62

One of the more effective recent uses of special effects to enhance rather than dominate a film was in the Lucas-Spielberg production of *Raiders of the Lost Ark*. Discussing the climactic holocaust sequence and other optical work in the film are ILM effects supervisor Richard Edlund, effects art director Joe Johnston, animation supervisor Sam Comstock, optical supervisor Bruce Nicholson, special makeup artist Chris Walas, cloud manufacturer Gary Platek, matte painting supervisor Alan Maley, and matte cameraman Neil Krepla. *Article by Don Shay.*

FRONT COVER — The fire-breathing Vermithrax Pejorative from *Dragonslayer*. The dragon swoops down to attack in the climax of *Dragonslayer* — BACK COVER.

COMPUTER IMAGING AN APPLE FOR THE DREAMSMITHS

image

article by
Peter Sørensen

Imagine yourself the director of a big-budget science fiction film, working on a special effects sequence involving the rescue of some endangered earthlings by a friendly alien spaceship. For this particular scene, however, instead of using models and motion control photography, imagine yourself employing the hottest new motion picture technology of the mid-1980s — computer-generated object simulation and electronic compositing.

You are working in a room full of electronic equipment, facing a wall of video monitors. You lean back in a chair with your coffee (or Heineken, if you prefer) while the technical director shows you the designs for some spaceships you worked on earlier. He punches a few buttons, and several screens light up showing different kinds of interplanetary vehicles, rendered in full perspective with absolutely convincing shadows and highlights. The ships look photographically real, and careful examination of any part of them reveals a wealth of subtle detailing. They have, in fact, been lovingly modeled — but not from cannibalized plastic kits, or any other material substance. Instead, they are like spirits in the machine — they are software spaceships.

You begin the session by loading the main computers: “All right, Bob, take the one on screen five — the one the producer liked — and dump it into the main box. And take the dolphinlike alien ship that’s on seven; we’ll use that for the rescue craft.” Bob loads the main computer with the data on the two ships from a disc storage unit that makes a few brief purring sounds. The chosen vessels now appear on the main viewing screen.

“Give us the environment with the neutron star we made yesterday, and program the star’s gravity to be twice as powerful as it was. I want things to move a lot faster this time.” Bob pokes at the keyboard again and suddenly the background is filled with billowing wisps of the Milky Way. A small silver orb shimmers in the center as if it were a vibrating droplet of mercury. Immediately the two spaceships start to fall slowly towards the neutron star. “Now the fun begins! Bob, you take the earthship. I’ll fly the dolphin.”

You flip a switch and a console that looks rather like the controls of a Piper Cub lights up in front of you. You glance at the storyboards one last time to memorize the scene and then pull back on the joystick and give her some gas. The sleek dolphin-ship loops over and charges up, filling the screen for an instant. Then it’s gone, leaving the earthship alone, relentlessly drawn towards the deadly star. Now you refer to a small screen on your instrument panel which shows your own ship’s point-of-view, rather than the “camera’s.” You maneuver around until you can see the star and the other craft on this flight-screen, and then slow your ship to a crawl.

“Okay, Bob, the camera is to follow the earthship at a slightly slower speed so she’ll appear to gradually get smaller while the star is coming closer. We want to make it obvious to the audience that there’s no time to lose if those folks are to be saved.”

There’s more fine tuning and tweaking until finally: “Roll the tape ... slate ... and we’re off!” A character generator — giving the scene number and other pertinent data — is momentarily keyed over the shot as the tape recorder starts up. Now Bob’s earth-clipper starts forward in earnest, a delicate blue-violet feather of flame emanating from its giant engine. You wait a moment and then open throttle once again. Like a motorcycle cop roaring out from behind a billboard, you gun your dolphin-ship at full power and charge into the picture. In moments you are alongside the larger vessel — both ships plunging towards the throbbing neutron star.

On the big editing screen, the two ships are beginning to foreshorten and turn bluish as they approach the speed of light. In a heartbeat all would be lost, but your scout-ship has one last trick up its sleeve — the legendary tractor beam that gives you a grip on the earthship, allowing you to turn them both around with a mighty thrust of your graviton engine. Your engine exhaust, the tractor beam, and other like effects are available for adaptation from an ever-growing software library.

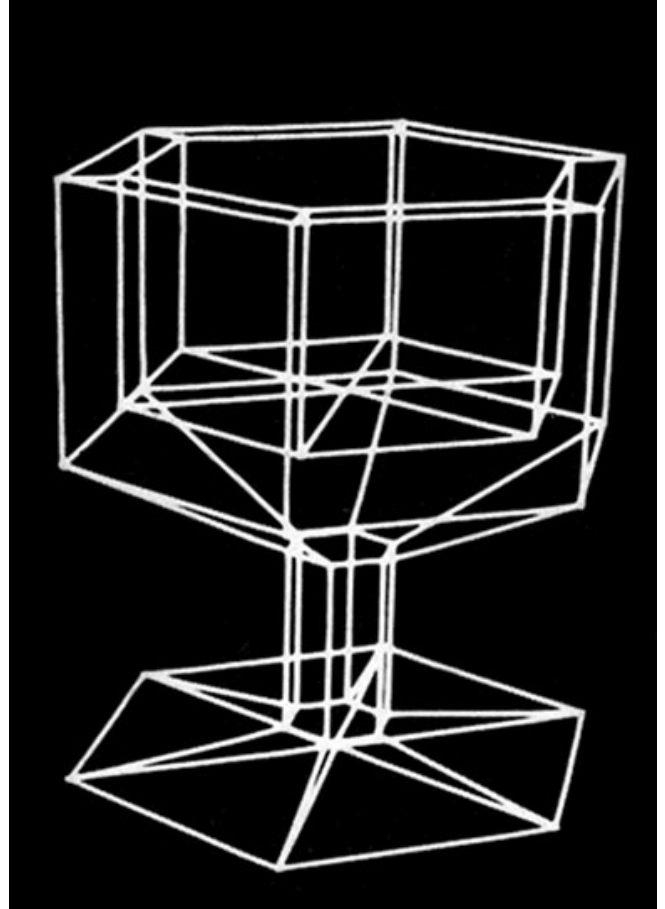
You can stop and do it over again — as many times as you need to get the perfect shot — or the computer can replay a take and let you go in and make adjustments. When you’re finally done, you can tell the computer to smooth out any rough transitions. Every step of the way you will be saving the necessary data on disc memory, so that all stages of the animation process are available for recall and thus there is no cause for hesitation about making changes or experimenting. Any setup ever made on the system can be recalled in a moment and used as is, or modified.

Hardware for such a system will be superficially similar in many respects to video technology (with all the freedom, speed and flexibility of that medium) but its final product will be a 35mm or 70mm film image of a quality far superior to conventional opticals. At its heart will lie a powerful “number crunching” digital computer that is actually a cluster of smaller computers with vast solid state and disc memories — a spin-off from the technology the auto and aircraft industries have been using for over a decade to assist in their product design. These so-called “computer aided design” techniques, coupled with the related field of image processing, have contributed to the effort to develop the machines and the programs whose creations are just now beginning their debut in motion pictures.

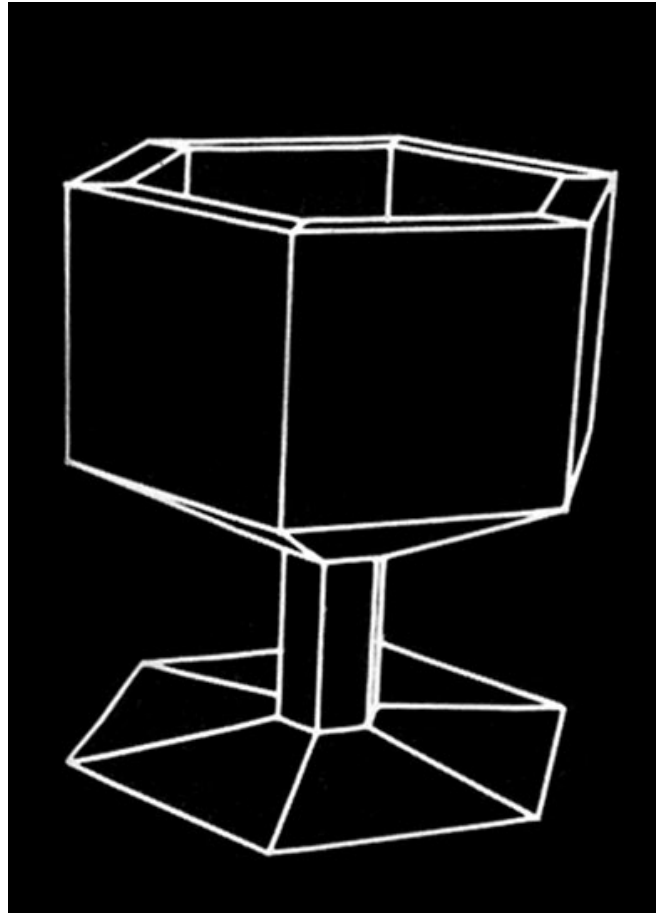
Today’s computer animation is almost up to the level of the cinematic system described. We’ve really only been stretching our imagination with respect to having so many different abilities all wrapped up in one fast and flexible package. But by mid-decade, electronic cinematography will be emerging on several fronts, with image synthesis and image processing — composited with live-action on video-like systems — being the most prominent. Such systems will not, however, be replacing motion control and existing special effects techniques so much as they will be blazing totally new territory.

There can hardly be anyone in the “*modern world*” who is not aware that electronics is a booming field, and most people also know that it’s all because of the ever-smaller-more-sophisticated-yet-cheaper micro-circuit technology. It was the invention of the transistor in 1947 that initiated the

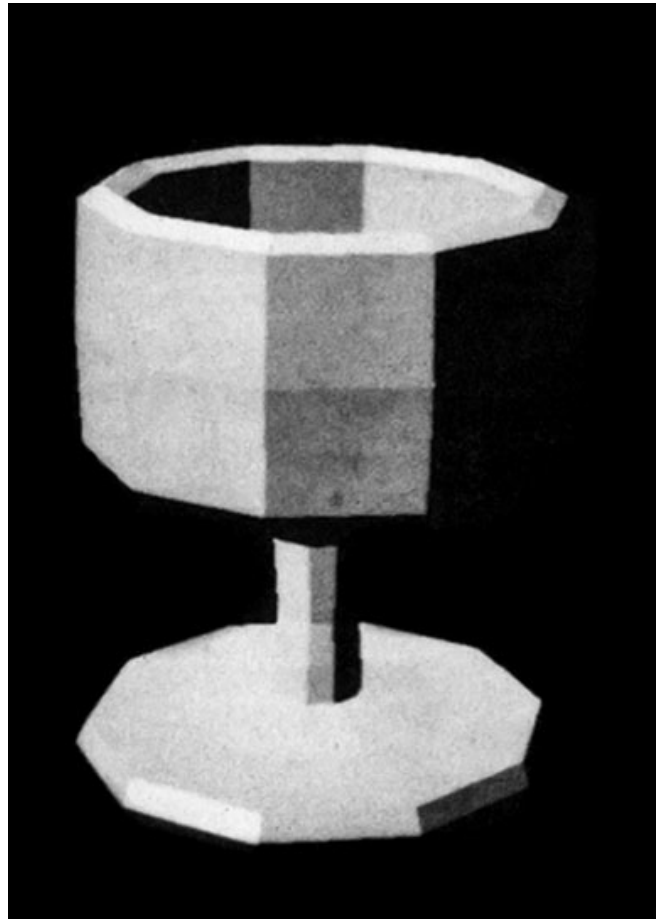
birth of the Solid State Age. By 1959, many transistors and other elements could be combined on “one tiny chip,” and the race for smaller and more complex integrated circuits was off. Over the years, the minute plastic blocks that contained the circuits grew very little, but under a microscope, their insides began to look like an aerial view of some huge city as eventually entire computers were being etched onto the silicon. Today’s microprocessors have a hundred thousand components; by 1990 they should have a million or more. Needless to say, the computer business is thriving.



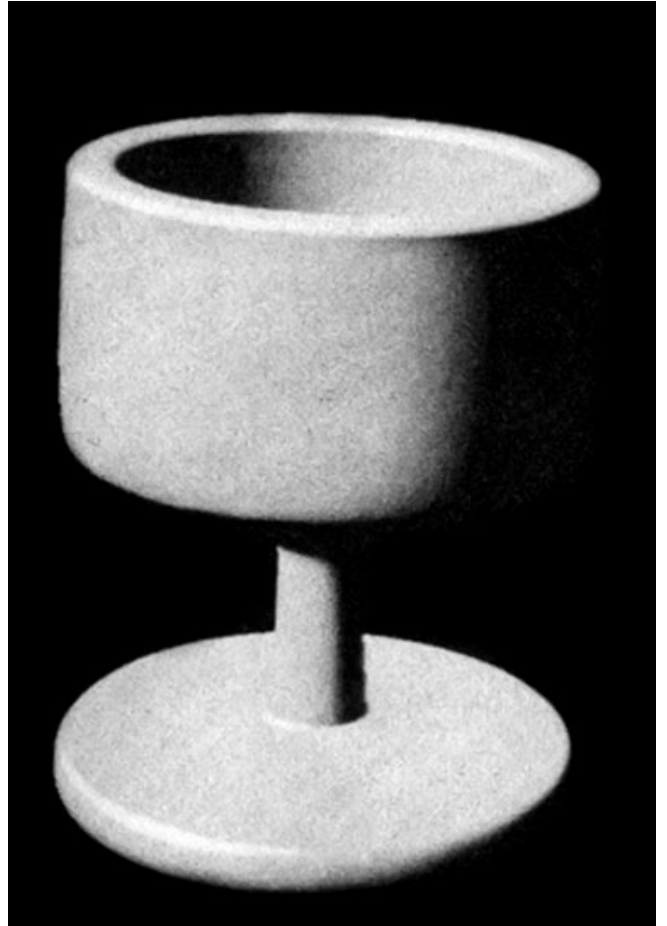
Dr. James F. Blinn’s “Evolution of a Goblet” presents a concise visual history of computer imaging. Early computer graphics involved the generation of calligraphic or vector displays — simple line renderings with all sides visible at once.



A major advance was the introduction of hidden line removal which allowed the computer to present an object from a specific point of view, but still in vector form.



Then, moving toward more realistic representations, computers began filling in the lines and depicting objects as a series of flat polygonal facets.



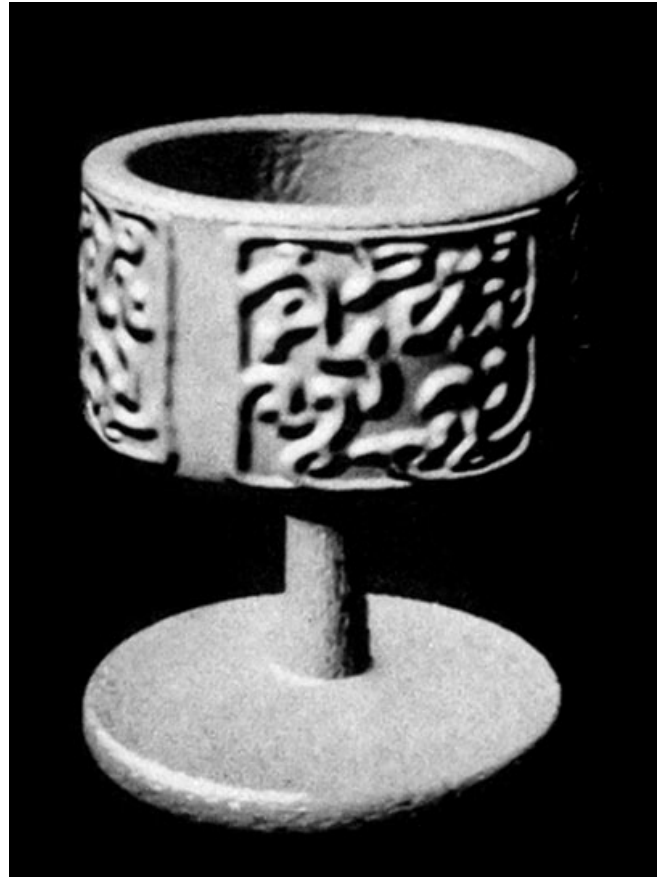
The next major step toward full image synthesis came with the advent of smooth shading, an averaging process which smoothed out the polygonal surfaces.

The video industry has also benefited greatly from the microelectronic revolution. Portable cameras and recorders would be impossible to carry if they had to be built with radio tubes inside. Unfortunately, however, the broadcast industry standardized itself long ago with a picture comprised of 525 horizontal lines, a resolution so poor that film-oriented people were convinced there would simply never be a time when video might compete with 35mm for theatrical use. But there *are* advantages to video. With video, you can record an image and play it right back, without waiting overnight for chemical processing. You can also manipulate colors and other aesthetic parameters, do dissolves and keys in real-time, and make many copies of a show simultaneously from one master — all possible because the picture is encoded into an electronic signal.

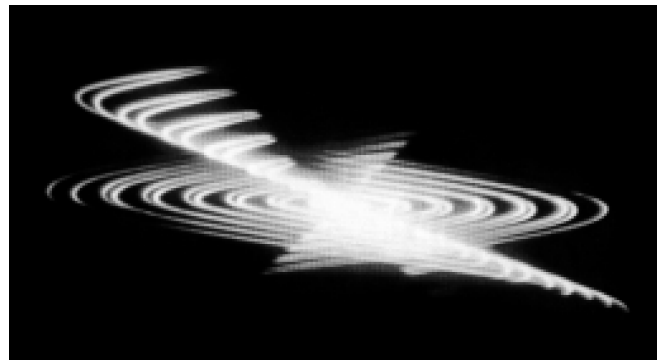
In film, to composite an object from one piece of film onto a scene from another requires complex optical techniques. In video, it's a breeze. In fact, it's done live a dozen times every night on the evening news. That big rectangular area behind Dan Rather's head is a chroma-key screen. Blue is used most often, but any color can as easily be used to key on, because it's a simple matter for a video switching device to recognize a color by looking for its electronic signature of shade and hue. Wherever it sees the key color, the switcher inserts another video source.

The latest advances in video involve the use of digital techniques which make for zero image deterioration over multiple tape generations, as well as squeeze-zooming and freeze-framing. So, it's not hard to see that if there were satisfactory image resolution, motion picture production — especially editing — could benefit from the broadcast industry's research and development efforts. But what's needed is a TV camera with a resolution greater than 70mm film — and the Japanese are hot on the trail.

For a long stretch of time, after the fall of Rome, Europe was plunged into the *Dark Ages* — a period highlighted by non-growth and the preservation of ignorance. But then, as surely as the mammals thrived while the dinosaurs died off, little pockets of learning began to grow; and with the invention of movable type, knowledge became a respectable personal attribute once again. People became



Today, raster graphic systems are able to inject almost limitless detail into their software images.



A scene from Peter Sørensen's "Scanimate Concerto," performed by Phil Zimmerman at Computer Image Corporation. The visual music was intended as background scenery for modern dance.

interested in how the world around them ticked. It became fashionable to drop feathers and steel balls from tall towers, and to peer through pieces of glass that were cut and bent in curious ways. Isaac Newton discovered that a triangular piece of glass could break white light into a rainbow of color, and that a second such prism could put *Humpty Dumpty* back together again. The pathway to the present was being blazed. Then, in the late 1800s, a Frenchman named James A. Lissajous stuck little mirrors onto rubber bands, and when he plucked them inside a darkened theater they bounced light around in beautiful patterns. In the 1920s, a Danish-American named Thomas Wilfred took advantage of the powerful new electric theatrical lighting that had become available to construct several large light organs. By means of hundreds of levers and wheels, he was able to control the lights, lenses, mirrors and colored filters in his “Clavilux” projectors, and as a result became very well known for his carefully scored lumokinetic performances.

After the first World War, we come to the invention of the cathode ray oscilloscope and the rediscovery of Lissajous patterns — this time made by using electronic oscillators to deflect an electron beam around on the face of a vacuum tube, creating pure sine/cosine wave patterns just like those formed by the vibrating rubber bands seventy-five years earlier. The first electronic computer was built at the end of the second World War and by the 1950s, the world was already beginning to feel the effects of the new technology. A man named Saxenian (his first name is lost to history) coaxed a digital computer into portraying the motion of a bouncing ball — the first computer graphics.

Basically, there are two quite different kinds of computers — analog and digital — with the key difference between them being the difference between waves and pulses of electricity. Digital computers perform calculations in binary math using distinct, individual, on-off pulses of current, while the analog devices perform their functions by manipulating electric waves of variable strength and frequency. A large number on an analog machine would be represented by a relatively high voltage, while a large number on a digital machine would be represented by lots of little electronic ones and zeroes. An abacus is technically a digital computer because either a bead is, or it is not, in a given location — there is no halfway. A slide rule, however, is a basic analog computer because its parts move smoothly in relationship to each other along a graded scale. Infinite variability is possible with analog, but down-to-the-last-decimal-point precision is not. These differences result in totally different areas of specialization for the two systems. Digital computers are used in tasks that require precision — such as keeping accounts — while analog computers are generally put to more intuition-oriented applications. Music synthesizers, for instance, are basic analog computers running at audio frequencies.

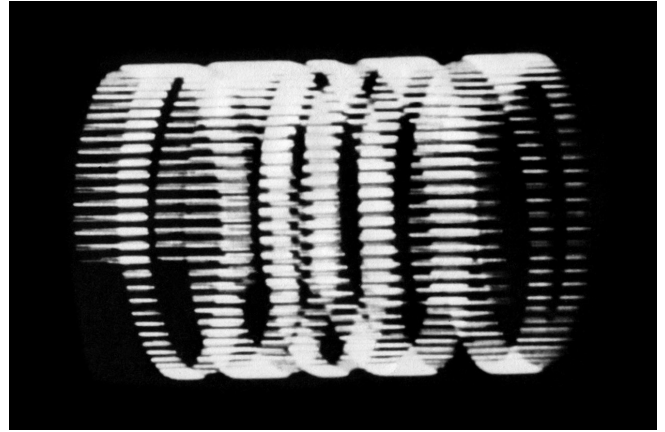
In graphics, analog computers are most commonly used for manipulating video pictures off a camera and making Lissajous patterns, while digital computers are best for synthesizing realistic dimensional images. “When you generate something in analog,” says veteran analog computer operator Phil Zimmerman, “it’s like asking somebody to grow a flower, to construct curves in the same way as nature does it. But when you do it digitally, it’s more like saying, ‘I can address each spot, one individual thing at a time.’ Whereas nature sort of conceives of things as a whole, the digital viewpoint conceives of things as little individual steps.”

Analog computers do not normally have magnetic memory storage like digital computers do. Nor are they programmed in the same way. On an analog machine the operator will construct a meticulously tangled mass of wires as each move is prepared. This “patch” functions somewhat like a telephone switchboard, connecting the many separate parts of the instrument so they all work together.

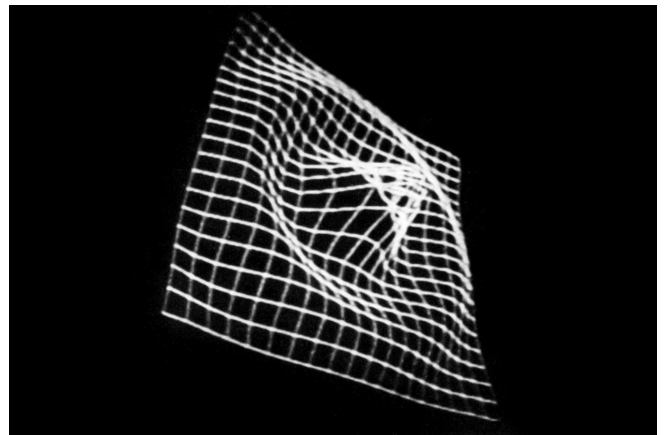
In 1957, the “father of computer animation,” John Whitney Sr., bought an old *World War II* antiaircraft gun controller — essentially a mechanical analog computer — and put it to the peaceful use of painting with light directly onto movie film by manipulating pinholes and shadow masks. And about that same time, an art and engineering student named Lee Harrison began experimenting with sophisticated ways of making Lissajous patterns using electronic analog computers of his own design.

But the early analog experimenters were regarded by a lot of people as mad scientists. Lee Harrison’s neighbors certainly thought he was more than a little peculiar, and surely no more than a handful of engineers understood his video dreams. Though he was ultimately to change the look of television, for several, often hungry, years Harrison recalls warming his house in the winter by the glow of hundreds of electron tubes.

In the Sixties, Harrison made a machine called Animac that could generate puppet-like figures out of high-speed wiggly lines. The puppets could even be animated by attaching an electronic harness to a live dancer. At the heart of the system was a high-resolution cathode ray tube, much like an ordinary TV picture tube. And like an ordinary TV tube, it featured an electron beam which made a spot that varied in strength to give light and dark, while being moved around by a fluctuating magnetic field driven by the computer. In standard video, the beam scans back and forth to fill the screen with regular parallel lines forming what is called the “raster.” The Animac, and its descendants, use the same electromagnetic positioning mechanisms for controlling the beam, but freed from the parallel sweep so they can make abstract designs based on the waveforms generated in the computer. Soon Harrison and his friends were creating the snazziest Lissajous patterns in history.



A Scanimate “Coke-roll” done at Dolphin Productions. The effect — which entails “wrapping” the video raster into a cylindrical shape that can be animated to unwrap and reveal its original image — is used frequently in television commercials, and is so named because of its initial employment in a Coca-Cola spot.



A video readout used on one of the medical bay monitors in Outland is an example of a familiar vector graphic image called a Bessel diagram.

A popular child's toy called "Etch-A-Sketch" comes to mind when discussing video computers, because the toy draws pictures — on a glass screen coated from the inside with silver dust — in much the same manner that its electronic big brother draws on a phosphor-coated screen with an electron beam. To make a picture on the "Etch-A-Sketch," one manipulates a scribe by the use of two knobs: one for left/right and one for up/down — it takes a lot of patience. In the computer, control of the electromagnetic field maneuvers the electron beam to make patterns in the same fashion. A different toy demonstrates yet another analog aspect — a toy that is, in fact, an analog computer itself — the delightful "Spirograph," a collection of little plastic gears and rings all meshed together to guide a pencil point through complex, loop-de-loop designs. By using different-sized gears, the gear ratios can be changed, resulting in a new pattern of spiraling loops. Something very similar happens in a video computer when it is generating its own abstract patterns. Instead of plastic wheels, however, there are changing magnetic fields; and instead of the gear teeth, there are variable oscillators powering the magnets, drawing with the electron beam.

But Harrison wasn't just playing around in those early days. He took his ideas to one wealthy investor after another — even to *Walt Disney* — but no one had the vision to see the value of his work. Then one day an advertiser said, "Come back and see me when you can make the letter A." Up to that point, everything he and his friends had been doing with the puppet-like Lissajous patterns was fairly free-form. They had not been manipulating whole television pictures yet. The solution was to adapt the system so that it manipulated an entire TV raster image, rather than just a squiggly line as before. Some of the most common moves that could be made with the new picture manipulation were imitations of common camera moves, such as pan, tilt and zoom. The more bizarre involved rolling the picture up into a cylinder or a ball, even turning it inside-out. That was in the late 1960s.

Obvious as it may sound now, the idea seemed pretty radical at the time. After all, the television industry had been spending untold millions to perfect a flawless, rock-steady picture. It must have seemed sinful to set about screwing the signal up! But Harrison and his associates began magnetically manipulating a raster as though it were a piece of electronic rubber and soon they had their letter A (and anything else they wanted) flipping, twisting and wobulating its way out over the airwaves. And so it was the Animac begat Scanimate.

Then Scanimate begat Caesar. Caesar is a machine with most of Scanimate's tricks, but with a small digital computer running herd on all the analog functions. (Such analog/digital teams are known as hybrid computers.) Caesar is capable of lengthy and complex moves which can be used to animate cartoon characters, a job that would be too difficult for Scanimate.

These days, Lee Harrison — with associates Bill Altemus, Dr. Ed Tajchman and others at Computer Image Corporation — are working on the next generation of hybrid video computer, called System IV, which will include the best features of the previous three machines, plus some new tricks which at present they are reluctant to discuss.

On the film front, John Whitney Sr. got started making non-objective motion pictures during the second World War, using an 8mm camera. Whitney produced these early films by photographing handmade artwork and then rephotographing those films on an optical printer he had built with his brother James. Eventually Whitney came to focus most of the creative process on the optical

printer. By his use of war surplus equipment he was able, with mere technological tablescraps, to create such films as *Catalog*, *Permutations*, and others that established him as the senior pioneer in technological art and motion graphics. (Lee Harrison, too, has built many wonderful machines; but he hardly ever used them himself, and none of his art has had public exposure.) Whitney went on to make several striking films and even some commercials and feature film titles. Then in the mid-Sixties he began working with IBM's digital computers on a research grant, and since then most of his art has been produced on digital computers. He currently teaches at UCLA in Los Angeles.

Also in the Sixties, several people were experimenting with various kinds of video-based analog computers, usually synthesizers. There was the Paik-Abe — an instrument that evolved as an extension of Nam June Paik's experiments using magnetic fields to create artworks out of old color television receivers. And then there was the Rutt-Etra machine, which was larger than the Paik-Abe, but smaller than a Scanimate. More Rutt-Etras have been built than any other kind of synthesizer. Most were bought by universities and individual video artists.

Then, quite apart from the scan-manipulation synthesizers, a new angle was being explored simultaneously, but independently, by two young video engineers in San Francisco, back during the days of Haight-Ashbury. The results were Steven Beck's Direct-Video Synthesizer and Eric Siegel's EVS. These systems did not manipulate the electron beam directly, so they needed no rescanning to produce the standard video signal. Instead, they generated their wild, op-art patterns within the context of the video sweep rate, a process that is something like weaving patterns into the blank video raster. But, like the Animac machine, these devices were also ignored by the business world — they were simply ahead of their time.

Except for the Beck and Siegel synthesizers, all the analog machines have in common the use of a standard television camera to translate their nonstandard images into ordinary video signals. This process is called "scan conversion" — from which the Scanimate gets its name. Scan conversion is necessary because almost everything the computers do involves distortion of the strictly regulated parameters of standard video. So the computer simply does its thing, playing it out on its own nonstandard, high-resolution picture tube, where the image is simultaneously being rescanned by the conventional camera, resulting in a standard broadcast signal. All of these various systems were developed primarily to afford creative people access to that magical electron beam in the picture tube, which had previously been totally off limits.

Analog computers have been used in untold thousands of television commercials and related work. Everyone is familiar with their distinctive electronic look. They have also been used occasionally for special effects in feature films. Science fiction fans will remember most of them; *Logan's Run*, *Demon Seed*, *Telephon*, *Hangar 18* and *Star Wars*.

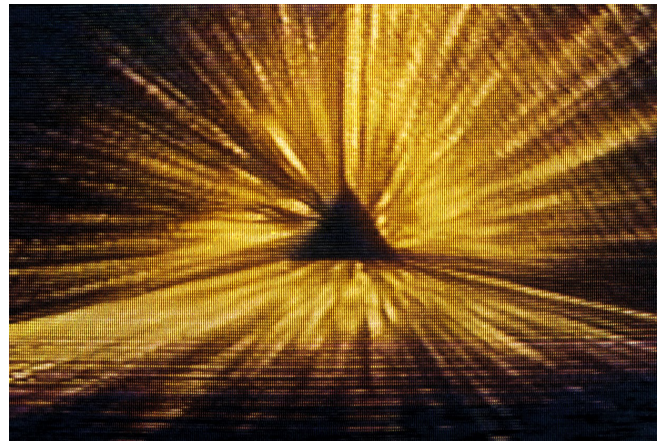
The problem, however, with using video computers for effects in feature films is that the 525-line television image is considerably lower in resolution than movie film. And even though there are new tape-to-film transfer techniques which use lasers to paint the image onto film in such a way that the lines are imperceptably blended into one another, the low amount of image information present is still troublesome to most film people. Nevertheless, these systems have been used quite effectively on a number of occasions — most notably perhaps in *Demon Seed*, a story, ironically enough, about a computer that decides to revolt against its human creators. To try and give the

audience a look into the mad computer's mind, the producers hired visual-music maestro Ron Hays to compose some effects. Hays and Scanimate operator Richard Froman came up with some classic visuals at Image West, especially the one for the computer's "orgasm" which made use of many abstract patterns of great beauty, as well as an analog computer version of slitscan. Earlier forms of slitscan — most noticeably employed in the "trip" sequence from 2001: A Space Odyssey — created a moving image with dramatic perspective by the use of a moving slit during a time exposure to control the light falling on film as a camera trucks in on a subject. Since with video there is no such thing as a time exposure (the video frame rate is an unvarying thirty frames per second) the optical slitscan method is impossible. But it is possible to squeeze and stretch a TV picture electromagnetically so that a similar result is achieved, using a Scanimate as Hays did. With the computer in the scanning mode, the portion of the image that is to appear farthest away is compressed, imparting a keystone shape to the raster. To give the effect of motion, the image is rolled — like a television out of adjustment — but because of the perspective used, the out-of-sync scanning makes the image look like it's zooming through space.

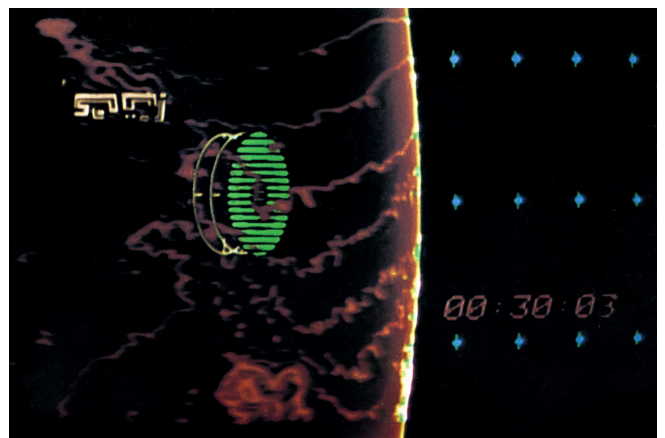
By careful planning in the optical department, and keeping the number of generations down to an absolute minimum, Hays was able to achieve satisfactory image quality, using the Vista-Vision film format. The Hays and Froman team also did some work on *Logan's Run*. In this case, the effects were combined with live-action photography as raygun blasts, glows and levitating force-fields.

For *Star Wars*, Jay Teitzell and Dan O'Bannon used Scanimates to create the big display in the rebel war room that showed the Death Star coming around the side of the planet Tatooine. The computer operator for the job was Roy Weinstock of Image West and the animation director was Domenic laia. Curiously, they wanted to achieve a look which would be like how the audience would imagine a *digital* computer display to appear, but achieved by using more economical analog equipment. The effect was originally to have been used as a rear projection in the war room set, but due to a foul-up, the screen was dismantled prematurely; and so it was added later in the optical stage with the help of a Ralph McQuarrie matte painting.

The title sequence in *Telephon* was also done with a Scanimate masquerading as a digital image display device. The story involved tiny electronic spy cameras, and Phil Zimmerman at Computer Image Corporation created an effect that was supposed to



Analog animation in *Demon Seed*, directed by Ron Hays and performed on an Image West Scanimate by Richard Froman, was used to portray the emotions of the film's super computer through abstract patterns which at times appeared meditative, angry, or — as in the case of this triangular video slitscan — orgasmic.



For the rebel war room scenes in *Star Wars*, Jay Teitzell, John Wash and Dan O'Bannon produced a computerized representation of the Death Star passing behind the planet

show what those cameras saw. More recently, *Time After Time* featured a time machine which travels down an abstract tunnel of energy done at Image

Tatooine. The Scanimate used was operated by Roy Weinstock, under the direction of Domenic Iaia.

West by Russ Maehl. The light shows that Lissajous gave in the 1800s were the direct ancestors of that time tunnel effect. (The wormhole effect in *Star Trek — The Motion Picture* appeared very similar, but was done on a digital system and projected with lasers.) Last year's *Hangar 18*, about a crashed UFO, made use of a brief analog animation sequence several times, whenever the alien viewscreen was turned on or off. The viewscreen was made to come alive as if it were a 3-D TV scanning its raster to fill a cubic volume. (Author Peter Sørensen was the designer/director of this effect, which was animated at Image West by Roy Weinstock.)

Analog computers have dominated the computer animation field for the past decade because digital imaging is such a massive mathematic task that it was not until recently that the systems became fast enough to be economically practical for animation production work. Until recently, in fact, most analog-oriented people said that digital technology would never give them serious competition. But despite recent advances in digital technology, analog systems are not likely to fall into disuse. Their great flexibility and speed will keep them cost effective for a long time to come.

Digital computing got its start with mechanical computing engines built by Blaise Pascal in 1642, which culminated in the hand-cranked adding machines common in supermarkets after the second World War. By then, the first experimental electronic computers were being built, using thousands of vacuum tubes as switching elements — and an enormous amount of electric power. The first big machines, like UNIVAC, even gained a certain degree of celebrity status for a while. In the Fifties, computers arrived in the business world, quickly making themselves virtually indispensable. Soon, “do not fold, spindle or mutilate” came to symbolize the dehumanizing side of data processing; and it was not until the recent micro-electronic revolution, with its home computers and video games, that people began warming up to the fact that computers can be thoroughly likeable little critters.

As the name implies, digital computers work with numbers — specifically the binary system, consisting of only ones and zeros. (Which is logical for an electric device since one and zero are readily represented by electric current being either on or off.) But computers were soon to become much more than fast adding machines as they assumed the capability of doing very long and complicated operations based on programmed instructions, even involving learning and decision making.

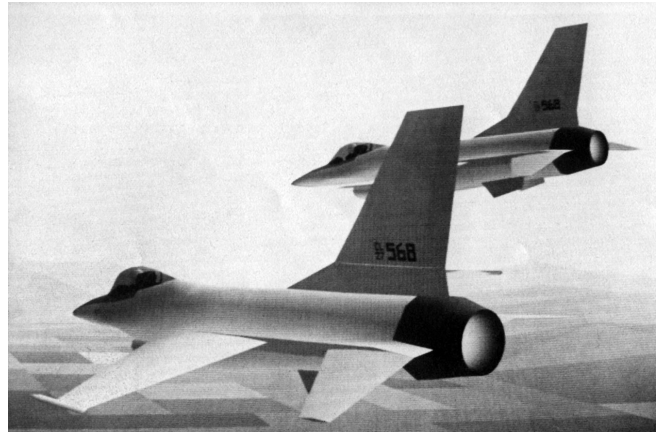
Computers vary widely in their applications, and their hardware configurations vary accordingly; but almost always they include a central processor where the main efforting takes place, a typewriter-like terminal for inputting data and commands, some kind of memory, and peripheral components that apply to the specific uses of the machine. Computer graphics setups might include such peripherals as raster or vector displays, plotters that draw with colored inks, film printers that employ electron beams, laser projectors and so forth. Inputting peripherals include X-Y coordinate digitalizing tablets for drawing, digital video scanning cameras, joysticks and other interactive devices.

Until recently, it has been difficult for anyone without special training to use digital computers because of their complex programming. The human/machine interface has been cold and regimented — springing from the needs of the machine — and not generally attractive to artistic people. But that is currently changing, with some digital systems now even more user-friendly than analog machines. But even if digital imaging systems had *never* gotten easy to use — if they were always expensive and slow-operating — they would still be about due for their day in the sun because they alone are becoming capable of creating images with photographic realism. Given the necessary data on form, perspective, color and light, along with more subtle information like texture and reflectivity, digital computers can display an object or scene from any viewpoint, as though the object actually existed, albeit in a massless state within the machines.

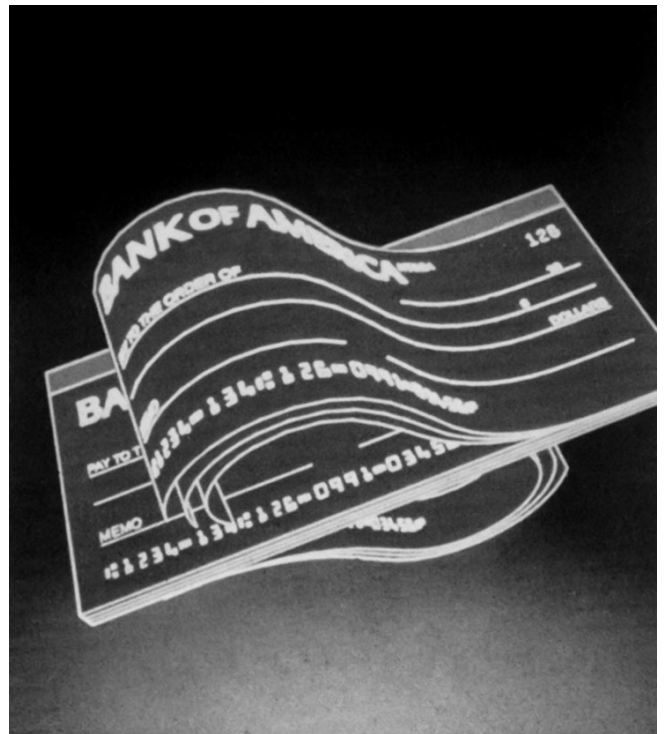
When an artist wants to make a painting of something realistic, he or she knows that success is dependent on several factors to create a believable image. Perspective, form, light, color, and more must all be imitated with perfection in every detail in order to elude detection and pass for a photograph instead of a painting. As a painting gets more and more realistic, it approaches a threshold of believability, at which point the scene is taken for an actual one. The task is so difficult, however, that you could probably count on the fingers of one hand the number of one-hundred-percent eye-fooling paintings you've ever seen.

Mastering perspective is one of the most difficult tasks for a human artist; but because there is a mathematical key to it, perspective is almost a trivial matter for the computer. By precisely calculating and rendering things smaller as they get farther away, the appearance of depth is strongly suggested, which is why computer images are frequently referred to as "3-D." They are, however, only two-dimensional perspective renderings and not to be confused with true stereoscopic images — which, incidentally, can also be easily generated by the computer.

Digital picture-making systems usually employ one or the other of two rather different approaches to actually producing their images — raster displays and vector displays. The raster method works very much like an ordinary television set, sweeping out parallel lines of changing brightness, while the vector method draws in random directions using the electron beam as if it were a pencil, following the contours of the object and not wasting any time filling in space where nothing is present. "Wire cage" outline drawings are typical vector displays, while shaded, solid images are typical of raster displays. Vector systems can be made to represent solid surfaces by filling them in with lots of parallel lines — a sort of pseudo-raster — but they do not have the ability to do subtle shading and highlights. Their advantage is that they are faster than the raster hardware and their software is less complex. But if the determining factor is realism in the picture, there is only one way to go — raster.



Vector animation done by Gehring Aviation for Bank of America demonstrates the computer's ability to twist and manipulate images.

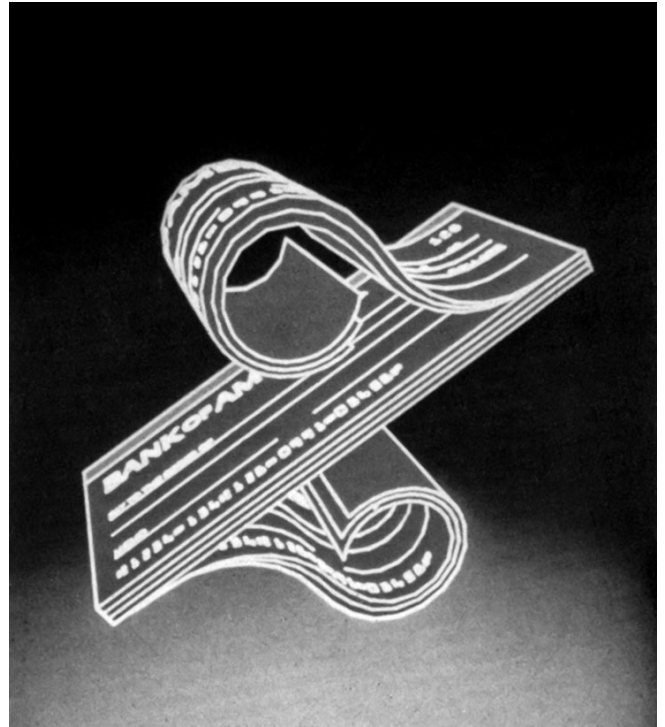


Gehring uses a pen plotter to draw the animation on paper...

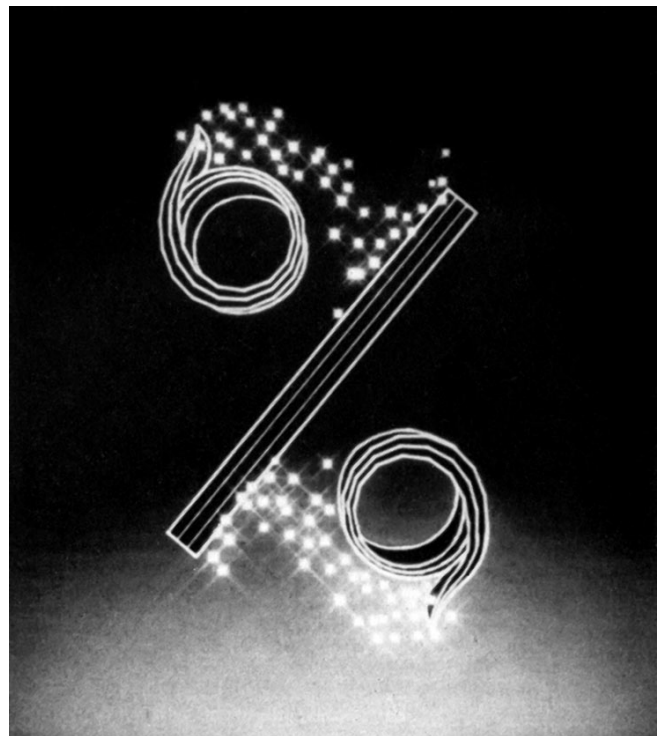
Raster display methods are most realistic because they mimic the phenomena of light as it is reflected off object surfaces, while a vector system, by comparison, makes a kind of animated blueprint. The raster system, however, is comparatively slow because it must calculate the color and intensity of each individual point (pixel) on each of the raster lines, while vector systems compute only the two end points of their calligraphic lines. Thus, a good high-resolution raster system may have to contend with four thousand lines with six thousand pixels on each line; and each pixel must be calculated for color and intensity — which is a staggering amount of work to be done for each and every frame. And all of that is *after* the machine has figured out the perspective and other physical characteristics of the object it is animating. In the end it may take as much as fifteen minutes or more to create a single frame of dimensional animation — although some kinds of animation can now be done in real-time at rates of up to fifty frames per second.

Curved surfaces are generally simplified and managed by the computer as a series of connecting flat surfaces that approximate the desired curve. By describing a curved object's surface as a large number of flat polygons, like the facets of a cut gemstone, a reasonable approximation of the object can be achieved. To smooth out the curves, the computer can perform what is essentially an averaging process between neighboring polygons. (Even many smoothly modeled images still have angular edges, since the edges have no adjacent surfaces with which to be averaged. If necessary, more work can be done to sand down those bumps.)

A problem that bedeviled software designers in the early days of digital graphics was the problem of removing hidden lines, and objects, from the scene when they were behind other things. Without a subroutine to tackle that problem, you would see all the surfaces at once — because the computer itself, in essence, “sees” the whole thing at once. Portraying the scene from a specific point of view is one of the most basic tricks the computer must perform. To find out if there are hidden lines or surfaces, it must, in effect, calculate plumb lines



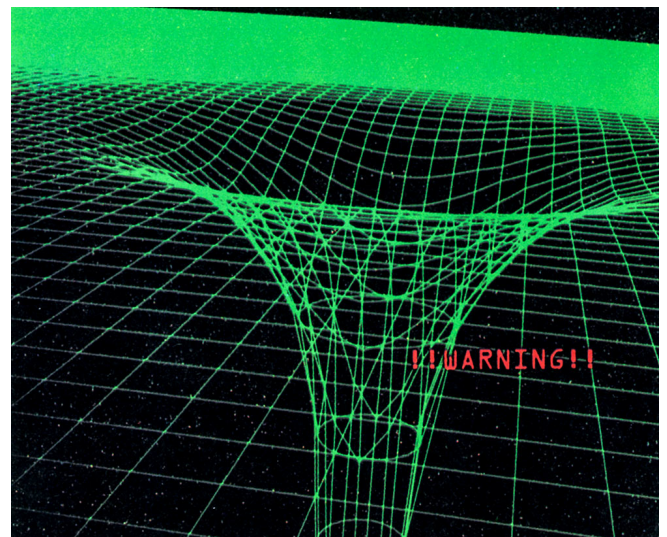
...shoots high-contrast negatives of the drawings...



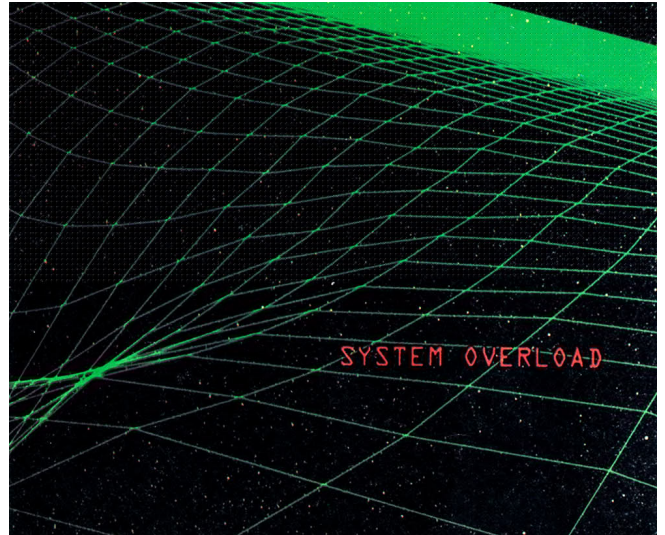
...and then rephotographs those negatives through color filters.

stretched from the objects in the scene to the viewpoint of a hypothetical camera, sort of feeling for an interruption in the paths that light rays would take on their way to the imaginary lens. If it discovers an interruption, the computer then knows it must drop lines that are in behind. But it has to think about it first. The computer must also perform a similar job in deciding when to ignore things that are out of the picture frame, otherwise the machine would be wasting its time figuring out a whole lot of unnecessary stuff.

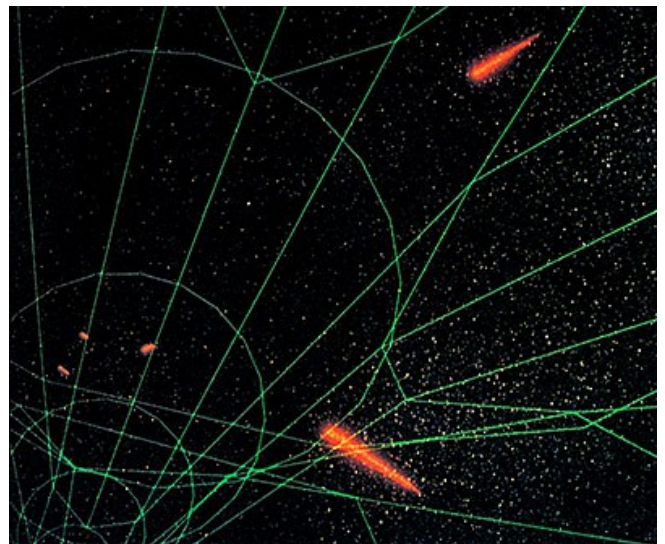
In the same time frame when Harrison was developing his analog systems, pioneering digital research was being done by a team of people associated with Dr. Phillip Mittelman at the Mathematical Applications Group, Inc. (MAGI). Their objective was the development of a pragmatic way to synthesize the appearance of objects as they would look to a camera. The system became known as Synthavision and serves as a good example of digital animation. "MAGI got started in the business of making pictures in 1967," Mittelman explained. "We had developed a series of programs for simulating the flight of nuclear radiation, and modified these programs to simulate the flight of light rays. In effect, we did a mathematical simulation of photography by tracing light rays from their source to the object being imaged, and then through a camera lens to the film plane. Using the laws of optics and reflection, we were able to make pictures with perfect perspective and shading. The key factor in our ability to picture objects was the way in which we described them to the computer. We built up every object from simple basic shapes such as spheres, boxes, ellipsoids, et cetera. These 'primitives' could be added or subtracted to finally produce the desired object. Object modeling in this manner is simple and effective. As time went on, we increased the number and complexity of the primitives until, at present, they number twenty-four. When using the Synthavision system to create movies, the art director produces the 'models' and makes pictures of them. He then uses an English-like language — the 'Director's Language' — to specify the motion of the objects, lights and camera. The computer adjusts the positions of the imaginary items on a frame-by-frame basis and calculates the picture which would be taken if all the items were real. This picture is output to a special color film recorder and is captured on 35mm or VistaVision film."



The title sequence for *The Black Hole* was programmed by Bill Kovacs on the Evans and Sutherland vector graphic system at Robert Abel and Associates.



When plotted out in “three dimensions,” the intense gravitational field of the black hole produced a funnel-like shape.



The animation, directed by C.D. Taylor of Neoplastics, with technical director John Hughes, was designed to take advantage of this dramatic form.

Architects are finding computer animation very handy. With it, one can stroll, as it were, up the streets towards a proposed structure, walk around it, and then go right inside and up the elevator to take a look out of the upper-story windows. For someone who is about to invest several million dollars in a building, it is reassuring to be able to visit it in such a manner before breaking ground. Cars and many other products are also being designed on computers that can give not only a view of what the product will look like, but can test the clearance of moving parts and other physical characteristics, and even generate blueprints.



Since the computer display was in black-and-white, colors were added with filters on separate passes through the camera.

Computer animation has been pioneered to a large extent by NASA and the aviation industry for the purposes of cockpit window displays in flight simulators. A great need existed for giving student pilots the experience of flying, without actually risking lives. The familiar Link trainers of World War II have evolved into some pretty impressive, multimillion-dollar hunks of hardware. Today's computerized flight simulators are mounted on hydraulic pistons that rock the cockpit for banking and turning, while the computer causes all the flight instruments to work, generates sounds and animates the view of the ground as seen from the plane. *The Singer Sewing Machine Company* bought the *Link Company* some years ago and has since been doing important research in developing real-time digital imaging systems — as have General Electric, Marconi Radar Systems, and Evans and Sutherland.

Simulators use raster displays to achieve natural lighting and color, but this is one application of raster technology where the computer cannot take all day to generate each frame of animation. For this reason, Evans and Sutherland developed the CT-5 system, which calculates images at the astonishing rate of fifty frames per second. This gives training fighter pilots a smooth effect of motion in their “dogfights.”

Flight simulation is done for spacecraft, too. In fact, the NASA moon walkers and shuttle pilots put in thousands of hours “flying time” before they blasted off from Cape Canaveral. But it was simulated views of the unmanned Voyager flights to Jupiter and Saturn that gave the public its best look at simulated imagery to date. Scientists working at the Jet Propulsion Labs in Pasadena wanted a way to preview what Voyager's cameras would see from various flight path options. Based upon the best available photographs taken from earth, computer animation pioneer Dr. James F. Blinn synthesized some truly beautiful motion pictures of the outer planets. In addition to these planets and their moons, the spacecraft itself was drawn into the computer and ultimately modeled from some seven hundred and fifty polygonal facets. Planetary surfaces were painted flat, directly into memory, and then by a process appropriately known as “mapping,” each flat surface was wrapped into a sphere. The resulting film product was widely seen by the public on news broadcasts and on Carl Sagan's *Cosmos* program.

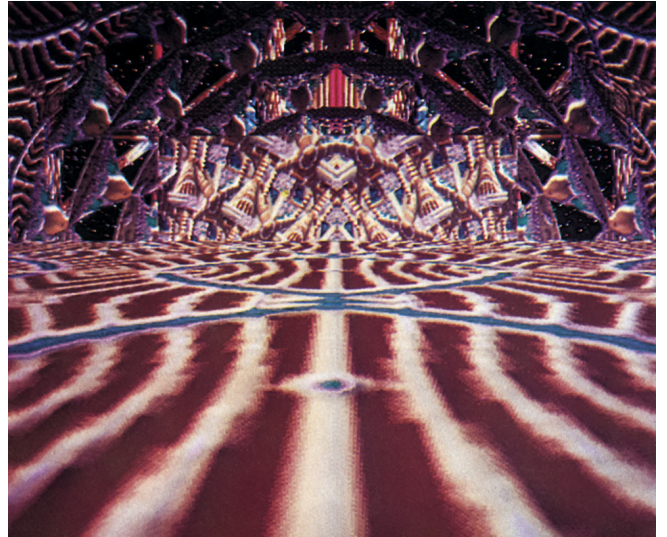
Blinn worked on the project with Charles Kuhlase, and together they also worked on several additional sequences for the *Cosmos* series, most notably the DNA animation, with its cloudlike molecules floating around. During the design stages of animation, they employed an Evans and Sutherland vector graphic system, which allowed them to view the choreography in real-time before committing it to film via their Automax instrumentation camera. Their central computer was a DEC PDP 11/55. Another sequence that JPL provided for *Cosmos* was an evolutionary metamorphosis that traced the major steps from primitive cell to human being. This was done with line drawings — not shaded graphics — and was digitized with the assistance of Pat Cole.

Perhaps the most luscious, totally out-of-this-world digital image synthesis being done is the jewel-like art of David Em, who works with Blinn's graphics systems on those rare occasions when Blinn himself is not. Em is an eclectic whose interests range from digital computers to theater and laser projections, and no one fails to be astounded by the surreal textural universes he creates on the computer with Blinn's modeling and painting programs. He literally paints and "sculpts" with the computer, taking advantage of the machine's ability to repeat and alter previously prepared elements. It is his fascination with texture that sets his art uniquely apart, since most image synthesis being done elsewhere is currently lacking in richness of texture.

Artists who use computers rely heavily on the data tablet, a peripheral input device which permits them to interact with their computers in much the same way as they would with a canvas. The computer works with numbers and the data tablet translates the motions of a pen-like stylus, or cursor, into information that the machine can use. It is very easy and natural to draw with, the only confusing thing being that the stylus makes no markings on the tablet itself; so the artist must watch the computer screen to see the results of his actions. Data tablets made by different manufacturers use different approaches to generating the electronic signals the computer needs; but the basic principle is that they have a grid of wires — like superfine graph paper — imbedded in a sheet of plastic, and the wires are sensitive to the location of the hand-held stylus. As the stylus is moved, the tablet is constantly sending updated information to the computer as to the changing X-Y position. The system was originally developed to let automotive and aircraft engineers digitalize blueprints.

image

The richly textured artwork of David Em demonstrates the wide range of possibilities for synthesized motion picture sets and digital imagery.



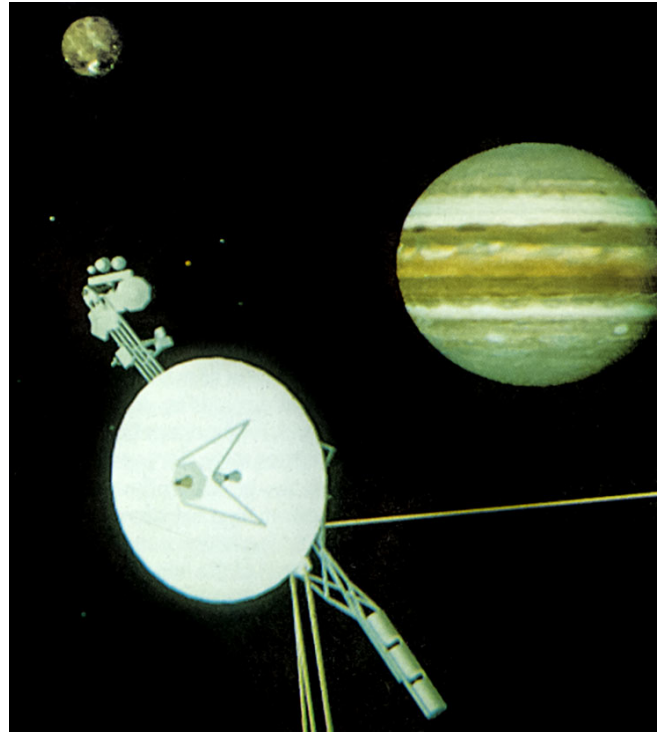
Em uses a DEC PDP 1155 with an Evans and Sutherland Picture System II and software by Dr. James Blinn.



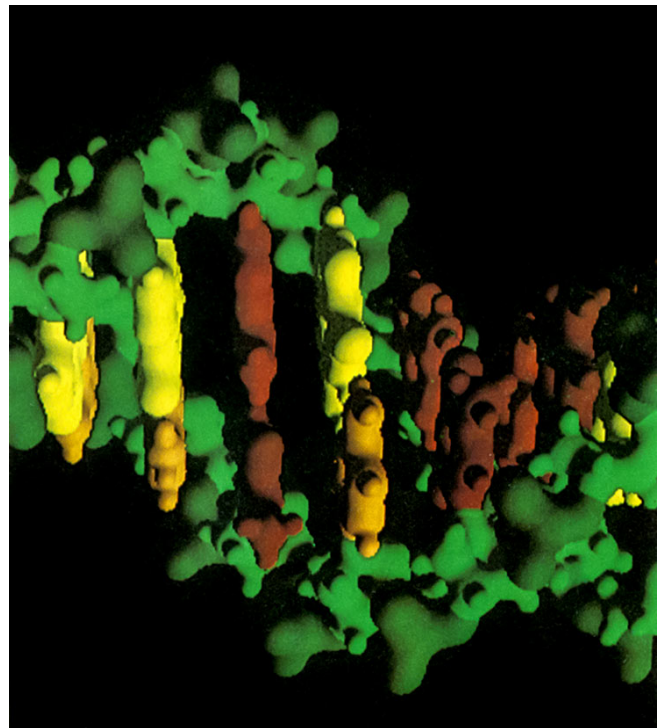
At the Jet Propulsion laboratory, Blinn, in association with Charles Kohlhase, produced the computer-animated projections of Voyager's trek to Jupiter, Saturn and beyond.

In use, the artist “seeds” his stylus with a color, selects the kind of brush stroke he wants (opaque, transparent, watercolor effect, oil paint effect, airbrush, charcoal, pencil, or whatever) and proceeds to draw on the data tablet while watching his results on the monitor. But this is more than just a gimmicky way of doing what can be more easily done with paint and brushes. Digital painting is faster than traditional methods because routine operations, like coloring in and repeating elements, are done automatically; and it is impossible to ruin something by mistake, because you can always go back to an earlier stage of the artwork and start again from there. Every step of the way is retrievable from the disc memory. Furthermore, just as the stylus recalls various kinds of paint brush programs, it can also be programmed to brush in entire pre-prepared designs at a stroke. For example, it is an easy matter to paint into the humming memory of the machine a landscape covered with hundreds of trees, and then zoom into any portion of that landscape and right up to the surface of any leaf. The process is actually done in reverse. The artist first paints some different leaves on the screen. The leaves are put into the memory for recall as needed. After a tree trunk has been separately painted, the stylus can be seeded with the previously prepared leaf design, and with this “leaf brush,” the tree can quickly be foliated by just tapping the stylus around on the branches. Some experimental paint sets will even distribute the leaves along the branches automatically, at randomly different distances and angles. Once a few different trees have been made, they too can be scaled down and used as “tree brushes” to populate a mountainside.

These painting systems are very “user-friendly.” In other words, they have no complicated controls or confusing procedures. On the Ampex AVA, for instance, all commands are given to the machine via the bit pad. You do not even have to type to be able to talk with the machine. Instead, you just touch spots around the border of the tablet that are



The sequences were widely shown on network newscasts and were featured in Carl Sagan's Cosmos series.



Also for Cosmos, Blinn and Kohlhase produced a sequence on the molecular structure of DNA.

designed for the various commands such as “color menu,” “brush menu,” “store in memory,” and so on.

Another device that is popular and easy to use is the joystick — a very straightforward, instinctual control that combines two or more variables into a single lever. Like on the old aeroplanes that first used them, you simply push the stick in the direction you want to go. Graphics can be moved about on the screen, or spaceships flown about in “3-D” space. Similar to the joystick is the trackball, which you roll in the direction you want something to move, and the “mouse,” a little gadget with wheels that you push around.

There are also touch-sensitive screens which feel X and Y movement, or the exact location of your finger. These are very effective for use by small children who simply have to point where they want the color to go. Similar, and less expensive, is the so-called light pen which can perform various functions just by being pointed at the screen. The light pen’s location is sensed by means of the pixel-by-pixel scanning of the screen’s cathode ray beam. Inevitably such user-friendly systems will speed the day when everyone will be “computer literate.”

Perhaps the ultimate interactive system in the world today is the computer graphics lab at the New York Institute of Technology, formed under the direction of Alexander Schure. NYIT has many workstations outfitted with data tablets and joysticks, each in touch with its host computers via a kind of data shock-absorber called a frame-buffer, which cushions the flow of information to and from the central processors. The time-sharing system employed allows for several people to use the art stations at once. Like JPL, NYIT uses DEC and Evans and Sutherland equipment.

Using data tablets for art input, the people at NYIT approach the production of computerized cartoons in very much the same manner as traditional cel animators. The artist paints in key frames on the data tablet to establish the extreme limits of motion and then tells the computer how long the scene should take. From there, the machine automatically generates all the “in-betweens” that are necessary. The animator can view the action almost immediately, and anything which is deemed unsatisfactory can be changed right away. If all those frames had been painted by hand, it would be an excruciating and time-consuming process to alter the scene. With computers, however, changes can be made easily right up until the last moment.

While the animation work is in progress, it is stored on large magnetic discs until it is finally scanned onto film or recorded single-frame onto videotape. Besides the freedom to change any

image

The first digital image synthesis in a feature film was produced for Futureworld under the direction of John Whitney Jr. and Gary Demos at Information International. Working from photographs of grid coordinates projected onto actor Peter Fonda’s head, Mal McMillan and Karl Brandt encoded a three-dimensional image of Fonda into the computer, which was then able to create its own representation of him for the cloning sequence.

image

Computer Creations produced a curtsying Raggedy Ann as a test for the Raggedy Ann and Andy cartoon feature.

image

Cartoon animation from the New York Institute of Technology utilizing computer software by Dr. Ed Catmull.

image

A scene painted directly into NYIT’s computers by artist Paul Xander Sr.

aspect of the animation, other advantages include being able to zoom an image up in order to paint in details, and the fact that there is no limit placed on the number of “layers” that a scene can have. (In conventional animation there are usually several layers of cels, each with separate arms, legs and so on. However, because the material they are made from is not perfectly transparent, there is a limit of about five layers which can be used at one time without affecting the background color.)

As if it were not enough to have the largest and most versatile computer cartoon animation setup in the world, NYIT is also one of the leaders in dimensional image synthesis. In fact, the folks there are currently busy making the first entirely synthesized feature-length motion picture, which has a working-title of *The Works*. It is a humorous story about a world populated by robots, with rocketships, space wars, conflict and adventure.

Dr. Lance Williams, the author and special effects director of the film at the NYIT Computer Graphics Laboratory, describes the work in process: “The computer models of the characters, vehicles, machines and buildings are defined in three dimensions. Their surfaces can be colored, patterned, and textured. They can be defined as shiny or dull, rough or smooth, or any gradation between. And they can be viewed from any angle, in any perspective, from fisheye to telephoto, illuminated by computer light sources of any color or intensity. The normal limitations of depth-of-field, intrinsic to any optical system and often important in using small models to represent large objects, do not apply to computer models. With enough computation, atmospheric effects, fog, shadows, and mirror reflections can all be simulated. Computer models are made of mathematical surfaces: spheres and ellipsoids, cylinders, cones, hyperboloids, paraboloids, polygons, and doubly-curved parametric surfaces. They are weightless and require neither wires nor pylons to flout gravity. They do not need dusting, gluing, oiling, repainting, or brushed-aluminum Haliburton luggage cases with custom foam-padded interiors. Thousands of them can be stored in a file cabinet. They enjoy, in short, most of the advantages of fantasy over reality. And the payoff, when the film comes back, are images that could not practically have been created by any other means. This is the most exciting prospect of the new digital techniques: that they are not simply a means of creating routine effects quickly and more cheaply, but that they make possible what could only be dreamed about before.”

The Entertainment Technology Group at Information International, Inc. (widely known as Triple-I), is probably the most advanced producer of dimensional computer animation. (NYIT might dispute that, but *Triple-I*’s current work with the human figure will be difficult to beat.) In the early days, under the leadership of John Whitney Jr. (son of the computer art pioneer) and Gary Demos, the Entertainment Technology Group produced the “robot vision” for the Yul Brynner gunslinger in *Westworld*, Peter Fonda’s head and the samurai materialization sequence for *Futureworld*, television IDs for all three major networks, and effects footage for several commercials. (Whitney and Demos have recently departed Triple-I to form their own organization, leaving the company’s current projects in the hands of effects designer Richard Taylor.)

Information International is not primarily a film production company. Their main business is making computer compositing systems and microfilm recorders for the print industry; but because they were already working with raster imaging technology, they had much of the hardware and software capabilities needed to do dimensional animation. As a result, Whitney and Demos were

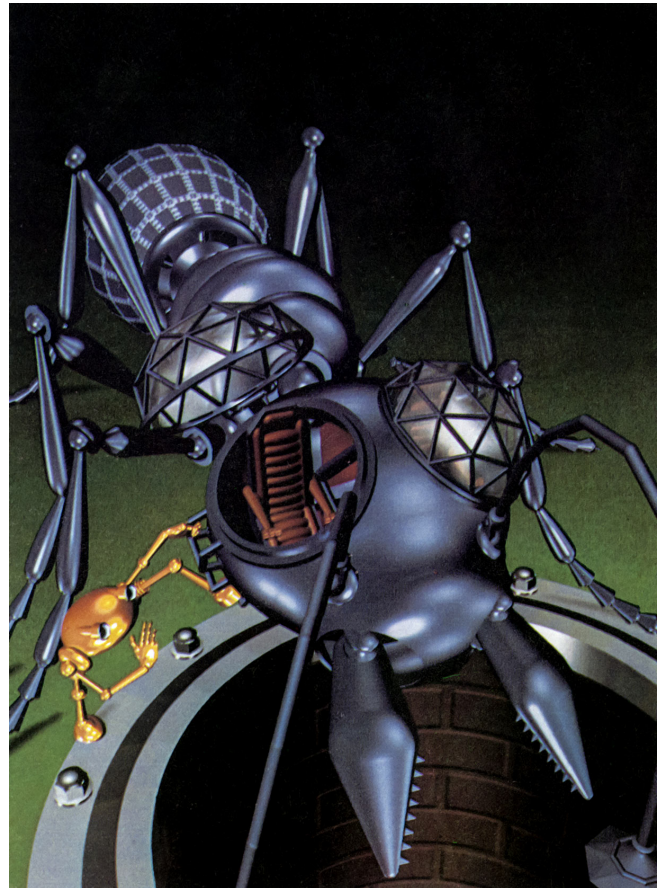
able to convince the company executives that synthetic image making would eventually revolutionize film making, and that Triple-I had an opportunity to get in on the ground floor.

The robot's-eye-view footage in *Westworld* was actually their first collaboration, done while Whitney and Demos were freelancing. What they had to do was process a series of live-action shots so that the audience would know the processed image was supposed to be what the robot was seeing. Basically, the image was sectioned into hundreds of square blocks, with all the detail in each box being replaced with a single color/shade arrived at by averaging the values of light and color that were originally in that area. The result was a mosaic that eliminated details, but retained enough information about the scene to be comprehensible. Ironically, high technology was used to produce a low technology look because, essentially, that was what people expected to see.

When *Futureworld* came along as a sequel, the Triple-I team was tasked with synthesizing Peter Fonda's head for a sequence that was to become a landmark in the growth of computer animation — a turnaround point where the fledgling technology really earned its wings in the entertainment field. The sequence involved the making of a robot clone of Fonda, and the animation was supposed to show various stages in the creation of his double's head. To achieve the effect, the Triple-I people took advantage of the computer's natural "3-D" processing steps, going from flat, faceted stages to the smoothed-out stage and finally to a lustrous, shiny surface.

The first step involved digitalizing the real Peter Fonda's face by covering him with white makeup and projecting a grid onto him. With his face thus contoured into lots of little squares, he was photographed from two angles simultaneously. The resulting pictures were then put on a data tablet and the important intersections of the grid were digitalized, giving the computer a data base from which it could model the face from any angle.

In the animated sequence, Fonda's head slowly rotates and tumbles, its surface changing at a subliminal rate from faceted to smooth. It also seems to change in substance — looking like plaster in the beginning and ending up like glassy porcelain. And while it is a truism that good special effects should be experienced but not noticed, it is unfortunate that most theatergoers never realized that what they were seeing in *Futureworld* was almost as remarkable as the fantasy it was meant to represent.



A mechanical ant and its diminutive pilot, *Ipso Facto*, from *The Works* — the first entirely synthesized full-length film — featuring ant design and modeling by Dick Lundin and production design by Bil Maher. The ambitious project is currently underway at NYIT's Computer Graphics Lab.

In the same film, Triple-I also introduced a sophisticated image processing technique in the so-called samurai dissolve. Unlike an ordinary dissolve, which simply tapers off one image while it brings on the next, the dissolve in this sequence involved the materializing of three samurai warriors from swarms of shimmering triangles. The triangles — originally quite large — quickly get smaller until they become like dots in a printed picture, so small as to be undetectable, materializing the samurai into solid existence. Making the men into triangles was, in a way, similar to the technique employed for the *Westworld* robot vision. Both involved a sort of pixelation process, which reduced the information on the images into geometric patterns which, in the case of the samurai, evolved into a normal-looking image. The overall sequence was achieved by shooting the set with a locked-off camera, both with and without the Japanese actors. Both shots were then fed into the computer, which could scan each frame and “recognize” the actors as being the only difference between the two shots — a trick the military does all the time with aerial reconnaissance photos. So, without the use of a bluescreen, the machine was able to isolate the swordsmen in the picture, and replace them with the triangle-patterns — in essence, doing all the required matte work electronically.

Then, around the time *The Empire Strikes Back* was starting up, Whitney and Demos came up with a plan to crack the industry’s long-standing skepticism over computer simulation ever being used as a process for producing full-screen scenes with a sense of photographic reality. To demonstrate their state of the art, they proposed to George Lucas that Information International produce a test shot for him featuring a flight of X-wing fighters. Working from models provided by Lucasfilm, Triple-I first made a set of accurate blueprints, which were then digitalized and encoded in the computer — a process that took six weeks to complete. Fortunately, the fighter was a symmetrical object, so the computer was able to assist by reiterating those parts that were common in the bilateral design. A special program was even written to allow the craft’s wings to scissor apart. Once the ship was encoded, the computer could duplicate any number of them; but to make each one somewhat unique, different battle scars and fuel stains were “painted” onto each. The test scene involved five of the totally synthesized X-wings, and though Triple-I and Lucasfilm were unable to come to financial terms, the viability of the technique was indeed proven to George Lucas who has since started up his own computer graphics division. The 22-person development team is headed by Dr. Ed Catmull, formerly of NYIT and the University of Utah, who years ago made history by synthesizing an articulated human hand. fool-proof image synthesis and digital film compositing are among the group’s stated objectives — as well as digital audio development and computer-controlled video editing. But don’t look for synthesized X-wings in the next chapter of *Star Wars* — because rather than channeling their energies and resources into applications that would put them in direct competition with their film-oriented counterparts at ILM the computer division is concentrating instead on developing techniques to achieve the kinds of things ILM cannot do, with the idea of fully integrating their unique technology into the overall Lucas filmmaking organization. Information International is currently working with two other animation facilities, MAGI and Digital Effects, Inc., on what is by far the most extravagant film project ever attempted using digital scene simulation — Walt Disney’s new science-fantasy picture, *Tron*, with Harrison Ellenshaw of Disney and Richard Taylor of Triple-I as its creative directors. Though details on the project are still under heavy wraps, the hero of the story is a computer programmer who is magically transported into a sort of

parallel universe of electronic games. The electronic world will be portrayed as if made of energy and light through the use of several advanced imaging techniques including synthesized environments created by the three animation houses, and also by making use of “candy-apple-glow” motion control techniques popular in television graphics. The candy-apple process was largely developed by Triple-I’s art director Richard Taylor back in the mid-Seventies when he was with Robert Abel and Associates. For *Tron*, it entailed shooting about an hour’s worth of live-action on black-and-white 70mm film and then rephotographing it through colored filters to get glows and other electric-looking effects. Many of the costumes were designed by the French *Heavy Metal* artist Moebius specifically to take advantage of Taylor’s painting-with-light technique.

More than twenty minutes of the film, however, will involve digitally simulated dimensional animation for the creation of fantastic vehicles and environments (many designed by Syd Mead, an old-hand stylist of the future whose work has been featured in *Star Trek — The Motion Picture* and in the forthcoming *Blade Runner*). This use of digitally generated sets is an historic milestone that future filmmakers will surely point to as the occasion when the impossible became possible — landscapes changing color and shape while gravity-free vehicles glide through the scene. Coupled with the glowing live-action and a number of more conventional effects (not to mention an adult-oriented script by director Steven Lisberger), *Tron* promises to more than make up for Disney’s rather disappointing venture into *The Black Hole*.

Recently, Triple-I has also produced animation for writer-director Michael Crichton’s latest picture, *Looker*. Crichton is familiar with digital methods by now, having brought *Westworld* (and by proxy, *Futureworld*) to Triple-I. For *Looker*, the principal effect needed was to make a synthesized dimensional image of actress Susan Dey — a job similar to, but more ambitious than, the Fonda head in *Futureworld*. Several other effects are also used to represent what happens when a computer is employed to analyze the human form in order to create the ideal human figure.

Perhaps the most interesting work being done at Information International, however, involves the progress being made toward animating the human figure. Prior to their work, the subtleties of human motion and form had proved elusive, almost impossible to simulate convincingly. In fact, many knowledgeable people stated flatly that it could never be done. The Triple-I team felt otherwise, however. “We thought it was absolutely necessary to do a human figure,” Richard Taylor explained. “It’s kind of like the ultimate in computer simulation. Otherwise, people would be bound to say: ‘Obviously, you can do geometric shapes. But can you do a human being?’ Well, we’ve *done* a human being. And he doesn’t just stand there — he juggles. We call him Adam Powers, and he’s incredible. He can walk in carrying his head, screw it on, become transparent, turn himself inside out, and do all kinds of things a normal person couldn’t do. Plus he’s standing on a geometric grid that spins around as the camera looks down on him from hundreds of feet away and then comes tumbling down and flies right through one of the objects he’s juggling. Busby Berkeley would have died for a crane shot like that. Adam’s motion has been driven by filming a real human juggler from front view and top view simultaneously, and then tracking points of reference on his body and encoding those into the computer. So the movement is not at all mechanical, because we have basically a data base that is the human figure. Underlying that data base is a skeleton, if you wish — actually dots with lines drawn between them — representing different segments of the body. So we film this live-action character and roscope the positions — front view and top view. We encode

those points to drive the skeleton, and then over that skeleton goes the fully-shaded character in tux and top hat. Then we can take that figure with that motion and place him wherever we wish.

“The data base that it takes to make a human figure is quite dense. Obviously, to do a face and hands takes a lot of data. His head, for example, and his hands were encoded from large drawings and then reduced, so they have more detail than the rest of his body. His hands have animation, and he can move his head, roll his eyes and blink — things like that. But he doesn’t speak, and we aren’t really changing his facial expressions right now. Those are other complex problems — ones that we know how to deal with, but right now we’re just trying to show that it is possible to make a human figure and to make him very lifelike.”

image

Stylized scenes of Times Square at night were produced by Digital Effects under the direction of Jeffrey Kleiser, with software by Judson Rosebush.

image

Electronic compositing was introduced by Frank Van der Veer and Barry Nolan in the recent flash Gordon. For the few scenes employing the process, their prototype analog system effectively eliminated matte lines and other image-degrading problems associated with traditional opticals.

After more than three years of development, Adam Powers made his professional debut at a recent computer graphics convention. True, he still looks a bit like a plastic doll, but his motion is astonishingly lifelike, and it doesn’t take a whole lot of foresight to envision his future offspring as totally believable electronic versions of the ultimate stuntman.

Other companies are also doing raster computer animation. Computer Creations in South Bend, Indiana, has a system in many ways similar to, but smaller than, NYIT’s. Independently developed by former aerospace engineers Tom Klimek and Richard Brown, the system, called VideoCel, is excellent for (but not limited to) cartoon animation. Earlier this year they produced a ten-minute film for the United Nations, called *Dilemma*, that is a blend of character animation and dimensional animation. Designed by the respected London animator John Halas, the film concerns the evolution of technological achievement and how it gets subverted into destructive uses.

Still another raster-type setup, called Acmecartoon, is located in Dallas, Texas. In addition to cartoons, as its name suggests, the firm also does image processing such as computer rotoscoping, image enhancement and pixelation. The most recently formed computer animation company is Digital Effects, Inc., in New York City, one of the three outfits working on *Tron*. Digital Effects is involved solely in dimensional image synthesis and has done a number of interesting commercial spots, including a series for *Scientific American*.

In addition to the production houses already mentioned, there are many research labs and universities involved with computer animation. The University of Utah, for instance, has been the breeding ground of many computer graphics geniuses, such as Dr. James Blinn and Dr. Ed Catmull. At the University of Illinois, Dr. Tom Difanti and Dr. Dan Sandin have been exploring just about every aspect of computer animation; at the University of Ohio, Dr. Charles Csuri has developed a handy, interactive “3-D” modeling system; and at corporations such as General Electric, Singer, and Bell Laboratories, important research is also being done — often under tight security. Of these, Bell Labs is probably doing the most sophisticated work, simulating the properties of light, such as reflection and refraction, under the direction of Turner Whitted.

On the basis of the foregoing evidence, it might seem that only raster graphics is used by film and television producers. Well, almost. But there is a little company in Venice, California, called Gehring Aviation, which uses a vector graphic pen plotting system very effectively, and a big company, Robert Abel and Associates, that uses the vector graphic cathode ray equipment. Both companies do much of their work with motion control systems but each has done outstanding work with line-drawing computers.

Gehring, for example, has produced a series of ads for Bank of America which anyone with a TV must have seen by now — glowing neon-like lines that draw a bank teller tumbling in space, or a checkbook curling up into a percent sign. These were done by photographing — through colored filters onto 35mm film — animation cels drawn on paper by the computer.

At Abel's, they shoot the computer display directly from their Evans and Sutherland Picture System II with a 35mm Mitchell camera mounted in front of the screen, also using colored filters because the Evans and Sutherland high-resolution tube is black-and-white. Using this process, they too have done many extraordinary commercials — most notably their spots for Levi Strauss, TRW, Bell and a Clio award-winning ad for Cannon calculators.

Abel originally bought their Evans and Sutherland to preview motion control sequences that were to be shot using models and/or graphic art. Subsequently, they were able to make the system so accurate that it could generate mattes for their model shots. One thing led to another and soon they were doing calligraphic animation with the setup. The principal software architect and senior technical director at Robert Abel's is Bill Kovacs. Widely known in his field, Kovacs repeatedly amazes the Evans and Sutherland people by doing things with their equipment that even *they* hadn't dreamed was possible. In fact, Kovacs comes remarkably close to the solidity of raster graphics with his vector machine, building up surfaces of objects with thousands of lines (matting out the hidden lines if he wants) to form a sort of pseudo-raster. Unlike true raster, which is horizontal and does not itself move, Kovacs' pseudo-raster moves with the object and is oriented with the object being modeled.

The Black Hole title sequence was done on the Evans and Sutherland by Kovacs, working in conjunction with director C.D. Taylor of Neoplastics. That animation consisted of a grid that was a gravitational field diagram, with a funnel-shaped well that represented the intense pull of *The Black Hole*. "Disney's *Black Hole* story boards were very similar to the final product," Kovacs recalled. "We took a couple of passes at it and then we generated a program for the flight path, because we needed something smooth and subtle. It was a lot of fun, because it involved some interesting moves on the black hole's gravity funnel — which was kind of curved, yet it wasn't. In a way, it was kind of like one of those old proverbs where the medieval king tells you to make something that is curved and straight at the same time. That's sort of the kind of object we were animating." The feeling of flying that the audience gets when they see the *Black Hole* animation serves to demonstrate the effective gut-feeling of depth that computer graphics can convey, even with a simple line drawing.

A similar type of animation was also employed in *Star Wars*. When R2-D2 finally arrived at the rebel base with his precious technical readouts of the Death Star, what the fighter pilots actually saw up on their viewscreen was a vector graphic animation display done by Larry Cuba at the University of

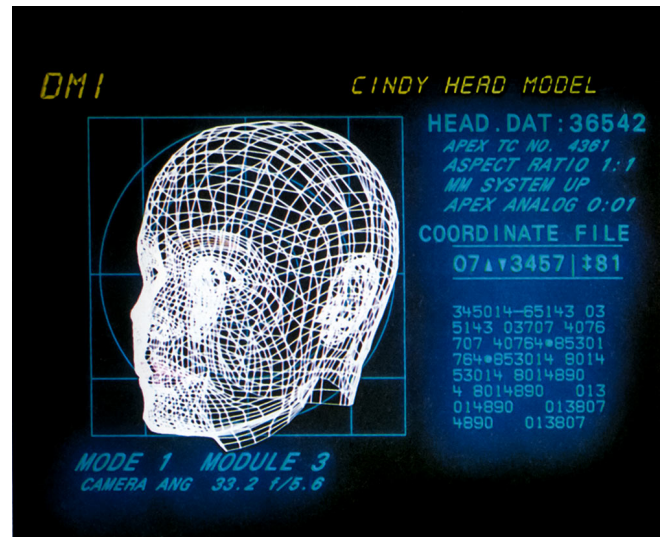
Illinois. To produce his footage, Cuba used a Vector General calligraphic display with a PDP 1145 central processor. First, he digitalized photos of the styrofoam modules that Industrial Light and Magic was using to build the model trench. Then he assembled these forms on the computer, going for “the texture rather than the absolute configuration,” since the final Death Star trench had not yet been built. George Lucas had specifically asked for a perspective rendering with the hidden lines *showing*, since he knew that would better represent what the audience expected computer animation to look like.

The animation came close to not getting finished on time, first because Lucas lopped three weeks off the time Cuba had to work on it, and second because of problems with the hardware. Somewhere in the bowels of his machine a tiny integrated circuit was behaving erratically and, as a result, it would not do the animation all the way through the twelve-hour shot without screwing up. Then, on the last night, when Cuba thought all was lost, he opened the window to the computer room and fell asleep on the couch. He awoke later and thought he would give it one more try. Breathlessly, he watched the computer go through the whole thing — without a hitch! Apparently the computer just wanted a whiff of the cool evening air. (Computers are notoriously fussy about temperature.)

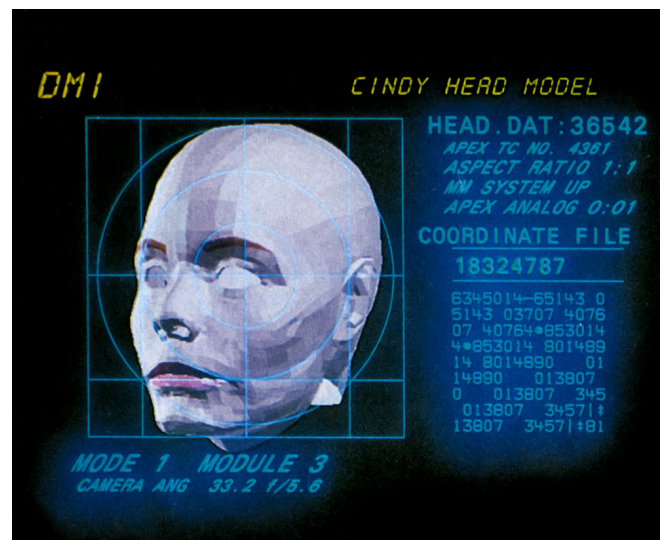
Just as *Star Wars* had a brief sequence of digital vector-graphic animation, so did *Alien*. During the landing approach of the *Nostromo*, viewscreens on the ship showed a line-drawing display of the terrain below, with jagged mountains looming up and a small valley in the middle. That instrumentation sequence (not the one showing a patch of rectangles) was done by Alan Sutcliffe of System Simulation, Ltd., in London. Originally, it had been planned to make a model landscape out of styrofoam and digitalize it, but that proved impractical and unnecessary since there were no clear views of the territory anyhow. Instead, the mountains were produced automatically by using a random number generator to determine their height and distribution. They were, however, controlled to the extent that none would occur in the valley landing area, and the ones in the rear would be taller on the average. The whole terrain was given a softly rolling contour by curving it slightly, based on the form of a flattened sine-wave. Minor touches included adding some ridges and a random perturbation that gave the landscape a more natural texture. All of this was laid out on a grid, using hidden line removal wherever there was overlap.

image

During production on Looker, actress Susan Dey endured a bizarre makeup session to prepare her for Information International's image synthesis team under the direction of Richard Taylor and technical directors Craig Reynolds, Mal McMillan and Mark Jaffe.



Once photographed from a variety of angles, the intersecting grid marks on Dey's face and body were encoded by Art Durinski and Larry Malone, imparting a three-dimensional image of her into the computer's memory.



The image was then played out in a sequence which flows from a "wire-cage" vector diagram to a polygonal faceted representation to a smooth-shaded rendering.

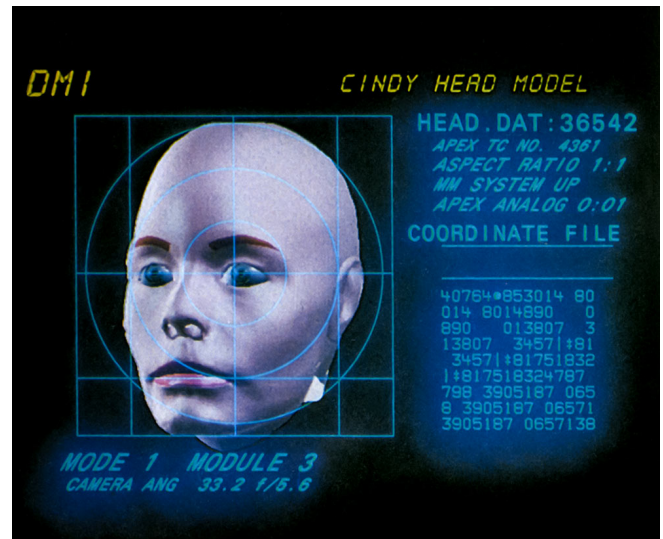
The animation shows the terrain moving up and leveling off as the landing progresses. Yet curiously, perspective wasn't necessary to achieve the effect because there were no objects — such as roads or buildings — in the scene that would have shown perspective convergence. Hence, there would have been scant advantage to calculating depth on mountains of random size during vertical descent.

Universal's Hartland facility — where the *Buck Rogers* effects were done — uses a relatively modest, but ingenious, vector graphics setup for designing scenes that would be shot using models, and to a lesser extent for generating some cockpit graphics.

Colin Cantwell devised the system, which uses a small Hewlett Packard 9845-B that could “solve three-dimensional problems in terms of their two-dimensional appearance.” Although it could not be used for real-time viewing — since it takes a few seconds to draw each wire-cage picture — the system did show successive stages of a move. Once the starting and finishing positions are entered into the computer via a data tablet, the system shows how the scene will progress; and on command, it will then print out on paper all the information the camera crew needs to set up the shot, as well as generate the pulses necessary to drive the motion control system. And it takes into account the spread of the lens being used, saving a lot of time and guesswork. The system was also used to produce instrument displays for the live-action fighter cockpits by shooting high-contrast stills off of the screen and sandwiching those with colored gels and glass. Normally, those types of displays would be limited to the ship designs already in the computer's memory, but on one occasion in *Buck Rogers* they had to make a display image that matched a specific shot involving ships not already digitalized. The problem was solved by rear-projecting the shot onto a transparent data tablet — in effect, rotoscoping on the digitalizing platten from the live-action shot.

“Computer languages are set up for numbers,” Cantwell observed, “and not for drawing pictures. So the graphics terminal on a computer has to deal with an operating system that was originally devised without pictures much in mind. That meant that there was a lot of work for the programmer on a very detailed level. He was having to work with how bricks are going together rather than what he was going to build out of them.” People like James Blinn, Bill Kovacs, Ed Catmull and the other software architects, work at this brick-by-brick level of invention, providing us with the programs that permit computers to be used as smoothly running digital paint sets and electronic modeling kits.

Traditionally, movies have always been edited by physically cutting and arranging sections of film, using a grease pencil to mark where dissolves and other optical effects are to occur. Optical effects themselves involve taking different pieces of actual footage and running them through prisms and lenses onto a single piece of raw film. Such procedures have always been necessary when mating special effects with live-action.



Lettering and incidental graphics were generated separately.

Clearly, the fundamental minimum unit in cinema is the individual film frame — these are the “bricks” of film editing and compositing. It might seem impossible to get any more fundamental than that in image manipulation, but in video the “bricks” are the individual pixels that make up the lines that make up the picture. (Technically, the crystals of silver in a photographic image are the equivalent of pixels in the sense that they are the finest elements in the picture. But filmmakers do not have control over these individual crystals, or grains, as one does digitally with pixels.)

As discussed earlier, when an image has been converted into an electrical signal which is processed pixel by pixel, it becomes possible to perform keys, dissolves, wipes and much more — right on the spot, in real time — because nothing physical (except electrons) is being manipulated. Live television makes use of these effects every day and nobody thinks twice about the magical simplicity of the process.

Unfortunately, though, we are still saddled with that Stone Age standard of 525 lines of video resolution. Until there are four-thousand-line TV cameras, the only way to have our cake and eat it, too, is to shoot on film, scan it, store and process the image in digital form, and not go back to film until making the final print. By using digital techniques, release prints could have (as far as the human eye is concerned) the same virgin quality crispness as the original take — because for all practical purposes, digital signals do not deteriorate from generation to generation. So in practice, you could actually make hundreds of passes through an electronic “optical” printer and the quality would still be equivalent to the first generation.

Information International is working on just such a machine, which they expect to have ready in the near future. “The problem with traditional printers,” explained Richard Taylor, “is that the film is more contrasty, more grainy and less color-saturated. Fringing in hair is a classic problem. They also are very time-consuming, labor intensive and non-creative to operate. Traditional opticals see the grain structure of the film and the best they can do is try to reproduce it. So, what we have done is design a system that compensates for film flaws. It is designed to know what the nature of grain structure is and eliminate that, so when it scans the picture on the high-resolution screen and it’s rephotographed, there is no grain build-up. The printer has greater resolution than the film has. It sub-scans the grain structure — it looks at the grain and it knows that the area should be a certain color. So when it makes the new picture it literally *knits* the image back together. With such a system, one can clean up film, enhance it, color-correct it, anamorphically compress it, stretch it, take scratches out. And it really gets to be magic when you start stylizing the image or combining live-action and simulation. For example, you could create a living Maxfield Parrish film by enhancing color, resolution and light.”

With a few scenes in the recent *Flash Gordon* feature, electronic compositing — using analog, though, rather than digital techniques — made its debut in the movie world. Frank Van der Veer and Barry Nolan built the history-making machines that processed those scenes, after twelve years of pioneering work. Their system consists of two film scanners for the scenes to be composited, an analog mixing device similar to a video switcher, a monitor, and a film printer that has four thousand lines of resolution. As the images are combined, the results can be seen right away on the low-resolution monitor. This allows the operator to rehearse the effect until perfect, and then print it. When doing a key, the machine's sensitivity can be adjusted in color and luminance to get the cleanest possible (essentially invisible) matte edge — and it is not limited to chroma-key blue. During compositing, the system allows the operator to reposition images, and to change the hue and chroma just as easily as it's done in regular television.

Perhaps the most powerful arguments in favor of electronic compositing are economic rather than aesthetic. "One way to cut costs is to compress time," said Van der Veer. "With all the steps that you usually have to go through with opticals, to the lab and back, to the lab and back, it takes you a week to do a shot. With this system, we've cut that down to a couple of hours. You can see your end result on the monitor before you send it to the lab." Looking to the future, Van der Veer plans to build a machine that will composite as many as six scenes simultaneously, and to incorporate magnetic tape as an intermediate storage medium.

In *Altered States*, Bran Ferren used digital film scanning techniques to generate traveling mattes for use with a conventional optical printer (4:65-70). In the scenes where Edward Jessup transforms into swarms of energetic particles, Ferren used computerized edge detection methods to separate the figure from the background. First the mattes were made using both computerized and conventional rotoscoping techniques. Then the fleckles were generated; and finally the figure, background and fleckles were all combined in an optical printer.

A more ambitious project involving edge detection and separation of areas from their surroundings is the work presently being done by Ralph Weinger for Douglas Brothers Corporation in transforming old "Laurel and Hardy" films from black-and-white into color. Weinger's system first transfers the black-and-white footage to tape via high-resolution scanning. At the beginning of



To show the film community that digital scene simulation was a viable alternative to shooting models under motion control, John Whitney Jr. and Gary Demos of Information International digitalized a Star Wars X-wing and produced a test scene for *The Empire Strikes Back* featuring five of the fighters performing aerobatics. Although Lucasfilm and Information International were unable to come to financial terms, the test was a success and George Lucas has since established his own computer development team.

every scene, each object or area of color is “spotted” (indicated to the computer), and the computer then does its best to track all these areas from frame to frame. It does, however, require occasional guidance from a human “assistant” when new things appear in the scene, or in other ambiguous situations, as when something is moving so fast that its location and appearance changes radically from one frame to the next. The machine works with great subtlety, calculating gradations of shading and taking into account soft-focused edges. And according to those who have seen the results, the effect is almost totally lifelike — not cartoonish at all. In some cases, the operators were even able to improve on the existing lighting, as in one scene where the two comedians were crawling through a tunnel carrying a candle. The entire set had obviously been flood-lit with a spotlight, but in the computer-altered version, light like that from the candle flame was substituted, flickering on their faces but leaving the tunnel dark and foreboding.

The processes used in *Altered States* and the updated “Laurel and Hardy” to detect edges and isolate areas, come under the broad heading of pattern recognition. Computers are acquiring many of the skills they will be using for intelligent matting and the like tomorrow from the image processing techniques used with CAT-scans and satellite photos today. Already, it is routine for computers to look for things in pictures and isolate those things from the background. They can automatically look for the color-signature of marijuana in reconnaissance images, and point out the pot with flashing red arrows. To do this, they mull over a quantity of data and then make informed “decisions” about what is, and is not, meeting the requirements of whatever they have been told to look for. Such processes will be put to work, even at a very academic level, for detecting scratch and dust marks on film. In such an application, the computer would look for anomalies that show up only on isolated frames, as dirt marks usually do. Having detected flaws in the image, it would then automatically fill in the defect with colors gleaned from neighboring frames. At projection speed, such a “band-aid” would be invisible.

Recently, work has been done in the field of artificial intelligence in which computers have been taught to scan snapshots of ordinary objects and recognize them by inferring from the 2-D pictures what the 3-D shape of the objects must be — sort of the reverse of synthesizing an image. Then the machine compares the 3-D form that it “sees” with those stored in its memory in order to actually identify the object. If we project where this research will lead, we can see that interesting possibilities exist for super-intelligent matting. A computer could, for example, be told to remove every telephone from an entire movie, just by showing it a picture of a telephone and saying: “Go get ‘em!” Then your super-intelligent image synthesizer could go in and substitute European phones (or anything else, for that matter) where each of Ma Bell’s phones had been. Bill Kovacs feels this is a very exciting area: “The challenge of processing real data — be it live-action, landscapes or whatever — taking those images and manipulating them, is potentially a much more rich source of imagery than just creating objects synthetically. You could separate everything that’s plaid from that which isn’t plaid, look at contour, outline, shadow, compare frame to frame. You could do a lot with that, and there’s a great need for it. Movie companies would come in and pay half a million bucks to save a scene, or replace somebody’s head with something else, or turn a daylight scene into a night scene. That’s the big apple — intelligent matting.”

Another exciting prospect for future image conjuring is indicated by the popular digital animation trick of transforming one shape or thing into another. In Carl Sagan’s *Cosmos* series, we mentioned

that there was a lovely example of the effect, used to portray the flow of evolution through dozens of topological changes. Imagine a super-intelligent image processor capable of “comprehending” the 3-D topology of two scenes and told to change one into the other. The machine would probably ask a lot of questions — like “Which details in scene A turn into which details in scene B?” — but it should be possible, *someday*.

With sophisticated image conjuring techniques we will be able to do research on how the human vision system processes impressions on the retina, how it encodes them and how the two optical nerves pool their information and come up with the 3-D picture that is delivered to our consciousness. Dimensional animation and image processing will assist in such research, and will then turn right around and apply what has been discovered to entertainment technology. Research done with biofeedback techniques and computer animation could have literally mind-blowing effects for entertainment — and mind-healing benefits in psychological applications. It may turn out that there are many ways to process live-action footage so as to trigger the brain’s 3-D “feelers” without having to rely upon stereoscopic photography. Using computers to doctor the focus of objects, heighten the contrast depending on how near/far they are, has already met with success in cuing 3-D perception.

Eventually, when the technology comes down in price so consumers can afford it, there is likely to be software available that allows people to have therapeutic encounter sessions and role playing, interacting with images that are tuned to open the mind’s floodgates. Perhaps “psycho-active computer animation” will come under the jurisdiction of government agencies, with only doctors being allowed to administer it. Probably not, but Daliesque movies loaded with subliminal Freudian imagery could be potent stuff.

True, *some* people get a little carried away when they speculate on the future prospects for computer imaging technology. Nevertheless, one can look to the research being done by NASA, the military and elsewhere to see that it is only a matter of time before the next generations of leading-edge software will percolate down to the private sector where outrageous new synergetic applications are bound to be found.

Several years ago, a remarkable chimpanzee named Washoe was going for a walk outdoors with her (human) sign-language teacher, when suddenly an airplane buzzed overhead. Washoe, who already had a vocabulary of several hundred words and was given to inventing some new ones of her own, pointed upward with a shriek of delight and signed: “Look, a car-fly!” Other chimps have learned to communicate with humans through the use of a special computer which has big plastic word-buttons that the apes push to form sentences. Such research is leading to important discoveries about how our own minds tick, and it is fascinating to think about what it would be like to communicate with an alien intelligence on a par with our own. Well, we may not have to wait for the flying saucers to arrive because there is mounting evidence that whales, and especially dolphins, are phenomenally intelligent, quite possibly our intellectual peers. These sea-dwelling mammals evolved into their present form long ago when our monkey ancestors were still swinging in the trees. And with their large brains, it seems probable that they developed language and oral traditions long ago. In addition to various squeaks and clicking noises, dolphins also seem to communicate using another, far more advanced method — sonar imagery. In essence, dolphins are probably living image synthesizers! The same lens-like organ with which they receive sonar images

from the water is also capable (from a hardware point of view, at least) of emitting images which other dolphins could “see” in the water. Although we have not yet succeeded in building a receiver which can translate the dolphin’s sonar language into pictures for our own eyes, there are people who are planning to do just that. Such research might very well focus on building an image synthesizing device that would be a sort of “3-D” sonar viewer. The translating machine should be capable of two-way communication, so it would have to be able to synthesize sonic images in the water at exactly the frequencies that the dolphins themselves use. For the human to communicate, there might be a keyboard interface similar to a Chinese typewriter, with its keys representing hundreds of basic sonar picture-words. If this scenario is someday realized as fact, we would be tuning in to a repository of ancient wisdom, alien and beautiful, which could profoundly affect our own human-centered world-view.

image

Information International has recently broken new ground by producing Adam Powers — an animated human figure who, among other things, can juggle with all the fluidity of his real-life counterparts. Art director Richard Taylor was assisted by technical directors Craig Reynolds and Mal McMillan in producing the sequence.

image

Encoding the figure was a monumental tasking in itself, accomplished by Art Durinski and Larry Malone. To get the motion perfect, juggler Ken Rosenthal was filmed in a body stocking marked with critical reference points. That film was then digitalized frame-by-frame so the computer could refer to that data base to animate the Adam Powers character convincingly.

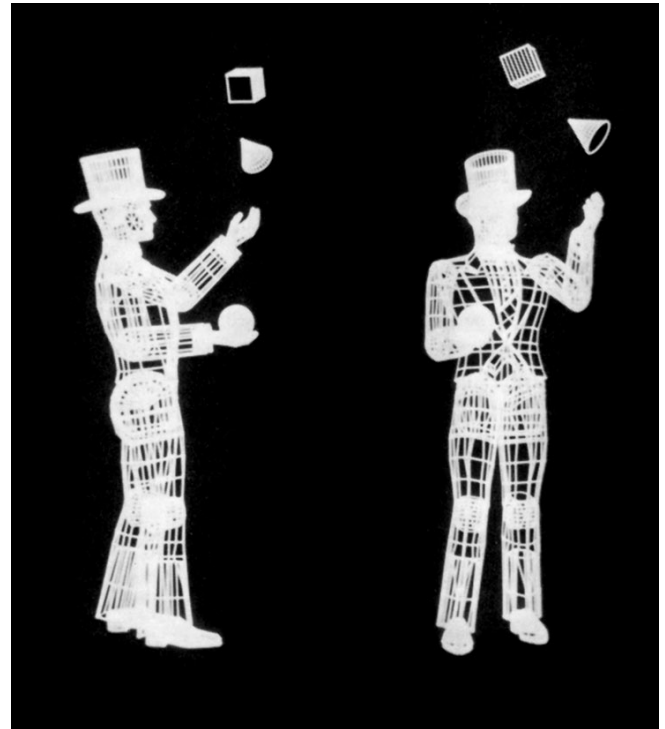
In the more immediate future, computer image synthesis could save the lives of countless animals that are currently being sacrificed daily in biology class vivisections. There would be little need for anyone, other than advanced medical students, to be poking around inside living cats and other creatures if there were inexpensive computer terminals, outfitted with lightpens, which could satisfactorily synthesize the action of a scalpel. In addition to the humane factor, such computers would have the advantage of being one hundred percent more convenient and sanitary. They could also be programmed to portray various pathological conditions and rare physical abnormalities that might otherwise be impossible for students to examine in detail. With stereoscopic imagery, Gray's *Anatomy* could literally come to life.

So clearly, there are many fields other than entertainment in which image synthesis can be expected to affect the world: computer games, driver education, digital art, psychotherapy — all are rapidly evolving from fiction into fact. It is no longer a question of *if* these things will become practical, but a question of *when*.

For *2001: A Space Odyssey* the model of the Jupiter-bound spaceship *Discovery* was a full fifty-five feet long. It was rather unwieldy but it had to be that big so it could be photographed with sufficient detail and depth-of-field to appear to be a quartermile long on screen. How many loving hours went into her construction we can only guess. Is making models on a computer any less, or more, satisfying? Obviously, it depends on the individual; and obviously a goodly number of individuals are already taking to digital imaging like flies to jam.

But while it will indeed be possible and desirable to freely improvise spaceships, scenery and so forth on the computers of the future, there will be a greater need for levelheaded planning and (ugh!) discipline. As the operators of the early Scanimate computers soon discovered, the near-infinite possibilities of the machine were booby-trapped blessings. It is so intoxicating just to twist the knobs and watch the pretty colors! And things happen so fast that you often make mistakes before you know it. The tendency, when faced with production deadlines, is to become stereotyped and superficial; and after a few years, a creeping cynicism seems to come over those who have been under pressure and forced to submerge their creativity for too long. The fact that one must earn a living tends to complicate the maintenance of one's personal creative integrity. But artists have always had to deal with that. Assuming one has the creative fire within, he or she must temper it with purpose and reason.

There is a mathematician named Tom Branchof who uses vector graphics to make movies about higher dimensions. He projects "shadows" of geometric figures down from as high as the fifteenth



Vector renderings were used to check motion and form prior to producing the final completed figure.

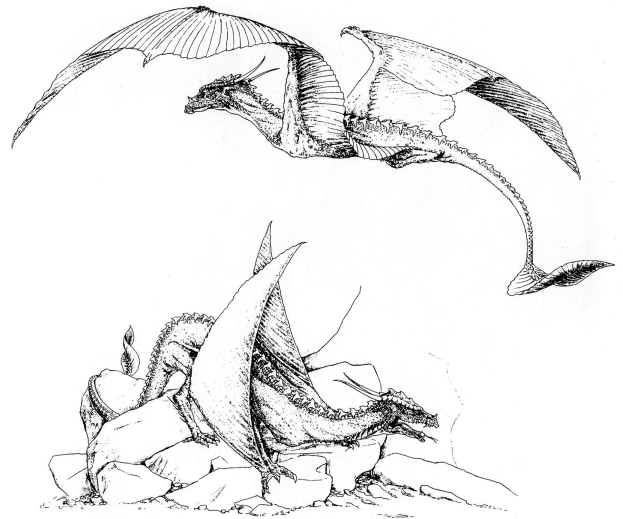
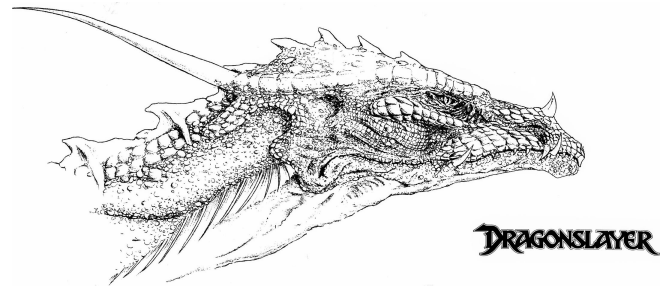
dimension (!) as moving models on his computer screen. The films are most beautiful and thought-provoking. He is an explorer who roams the theoretical stratosphere of space-time, taking his viewers through the digital looking glass and showing them the very weave of creation.

We are poised at the beginning of a new age of entertainment. Synthetic rocketships, electronic scenery, alien lifeforms, actors sheathed in electronic armor, digital prosthetic makeup , software botanical gardens, computer compositing and all the rest, will go beyond the mere imitation of the special effects of the past. With our new digital alchemy, we are breaking the laws of physics and truly pioneering new universes. Perhaps early in the next century, every home will have an image synthesizing console. The most creative artists in the medium will become international superstars, and philosophers will debate the existence of software consciousness. The pathway to such a future is already being marked.

Peter Sørensen is a Los Angeles-based computer animation consultant. He first became involved in using technological tools as art media at the Cranbrook Academy of Art in 1962. He was a designer and director of computer graphics commercials at Computer Image Corporation and Image West, and was involved with image processing on Hangar 18 and an unused transformation test for Altered States. Sørensen's writings on computer imaging have appeared in Millimeter and Videography.

DRAGONSLAYER

article by
S.S Wilson



In 1979, Matthew Robbins and Hal Barwood found themselves embroiled in trying to put together a romantic comedy. “We found it enormously frustrating,” Barwood recalled, “and ultimately impossible to get someone bankable for the female lead and for the male lead simultaneously available at any time of the year anywhere. We thought, ‘There’s a way to free ourselves from that kind of pressure and also head for a different kind of territory in terms of commercial possibilities.’ What we particularly got interested in was taking the maturing special effects technology, as seen in *Close Encounters* and *Star Wars*, and adapting that to a different kind of storytelling-dramatic venue which we liked better; and that was a fantasy idea.” That decision led to a film starring Vermithrax Pejorative, easily the most impressive dragon ever put on the screen, brought to life using the first genuine advance in dimensional animation technology since the process was invented.

Barwood and Robbins had never made a special effects picture. *Dragonslayer* is, in fact, their second film as director and producer. They were first a screenwriting team whose produced works included *The Sugarland Express* (directed by pre-*Jaws* Steven Spielberg), *The Bingo Long Traveling All-Stars and Motor Kings* and *MacArthur*. Then the urge for creative control overtook them, and they made *Corvette Summer*, directed by Robbins and produced by Barwood.

Though *Dragonslayer* is their first effects film, the duo had a long history of intense interest in fantasy, and some of their unproduced screenplays featured fantasy and science fiction. Furthermore, they were able to learn a thing or two from their friends. Besides Spielberg, they were

USC film school chums with George Lucas. “Matthew and I stood around very closely on the sidelines when *Close Encounters* was made. We watched Industrial Light and Magic as it was formed. So, we were close onlookers if not actual participants; and as a result, we had our wits about us when we started our project.”

One thing they were sure of was that they should try to obtain the best possible special effects experts; and it just so happened that Lucas’ Industrial Light and Magic would be available during the lull between *The Empire Strikes Back* and *Revenge of the Jedi*. “The first requirement,” Robbins insisted, “was that if we *did* do a movie about a dragon that we *deliver* a dragon. We were very, very committed to the idea that it would not all be people staring past the lens reacting to something over your shoulder — that eventually we would run up against it. And I think that had it not been for our association with ILM, we never would have undertaken it. It’s too terrifying to think of spending all this time on a movie and then coming up with a rubber duckie that’s going to flap and squawk. We knew enough about ILM’s operation so that we thought we could protect ourselves from some of the worst problems that would afflict a special effects movie, especially a special effects movie that would not command the biggest budget in the world. We just didn’t have enough of a track record going in to sell a \$27 million movie.”

Barwood and Robbins set to work on the script, applying their armchair effects experience. “We designed it so that the dragon would be in the movie as little as possible and yet be satisfying,” said Robbins. “And we always felt it would be safer to keep the creature in the dark, so you didn’t see the wires and the hooks and the levers and the matte lines. So the dragon was always appearing in dimly lit circumstances. Even in the final battle the level of light was low because of the eclipse, which was brought on purely to help the special effects: ‘Uh, get the lights down! He’s comin’ back!’”

As the script progressed, Robbins and Barwood determined that a series of color illustrations would help sell the project. They turned to David Bunnett, a carpenter-turned-remodeler-turned-graphic artist, who had once worked — alongside Robbins’ wife, Janet — on a small all-volunteer newspaper, illustrating a weekly children’s story about a wizard, a young boy and a dragon. Bunnett was at first reluctant to become involved, however remotely, in motion pictures, but Robbins managed to entice him into taking on the preproduction assignment. Then, with script and illustrations in hand, Barwood and Robbins shopped the project around Hollywood during the summer of 1979. Film fantasy in the *sword-and-sorcery* vein was a decidedly unproven commodity at the time, and it was only after a lot of intensive persuasion that they managed to interest Paramount.

By late fall, key members of the production team were being gathered: mechanical effects supervisor Brian Johnson, winner of back-to-back Oscars for his work on *Alien* and *The Empire Strikes Back*; director of photography Derek Vanlint, architect of *Alien*’s eerie cinematography; and production designer Elliot Scott, whose career spans a goodly portion of film history.

Brian Johnson laid down the first rule for the effects-oriented picture. “He made us run right out and start storyboarding,” Barwood recalled, “because it is impossible — you learn right away in making a movie like this — to get any idea of what the costs might be without having a detailed

knowledge of exactly how pieces of film are going to cut together. And the only way you can do that is by drawing the storyboard first.”

Bunnett stayed on the project, working closely with Robbins and Barwood on the dozens of preliminary storyboard illustrations needed for the producer-director team to begin adequately communicating their ideas — not only to Brian Johnson, who would be handling the complex stage effects, but also to the ILM *Dragonslayer* unit formed under the supervision of Dennis Muren. (Since ILM would be handling effects for both *Dragonslayer* and *Raiders of the Lost Ark* simultaneously, the facility was divided into two units. Muren, Phil Tippett and Ken Ralston became the key dragon effects people, while Richard Edlund and another crew worked primarily on *Raiders*. Bruce Nicholson of the optical department, Sam Comstock of animation, and a few others would divide their time between both shows.)

“At this early stage,” said Muren, “we were uncertain as to what our individual functions would be. We were to create the dragon, but it hadn’t been designed yet. Who would do that? And just what techniques might be used to execute these shots? It turned out that they had already decided how some shots were to be done, and that was with a full-size dragon head and neck — fully-mobile, fire-breathing, everything. Well, we’d seen the past results of this kind of thing in Dino’s *King Kong* — and even in *Empire* where they made three full-size tauntauns to use in Norway, one of which was supposed to run.” The ILM staff voiced their concern over the decision to rely heavily on large-scale mechanical props, but Matthew Robbins felt it was worth the gamble for the realism of actually having the actor and dragon together, on stage.

In the meantime, Elliot Scott assessed the project’s scope and determined that he would more than have his hands full with just the sets. (Over the next year, he would design eighteen sets, plus a four-acre medieval village.) Realizing that the design of the dragon would be a major effort in itself, he suggested that it be turned over to someone else. The job fell to David Bunnett.

As Scott predicted, it was no easy task. The script called for a dragon that could both walk and fly credibly, and Barwood and Robbins had definite ideas about what would and would not constitute their creature. “It’s a beast with magical origins,” Barwood explained, “but nevertheless we always had thought that it ought to obey the various rules of evolutionary biology. As a vertebrate animal, it only gets to have four limbs, you know — so there’s no four feet and then wings on the back; the front feet have to also be the wings. The basic model is a flying reptile called the rhamphorhynchus. If you’re into pterosaurs, you know that there are some that had no tails at all and instead had long back legs that extended outwards to create tension on the wing membranes. Rhamphorhynchus, on the other hand, had a very long tail with a sort of spatulate piece at the very back, like a leaf, which

image

Since the original intention was to rely heavily on full-size articulated dragon props during principal photography, the Disney special effects shop was engaged to produce a giant head and neck, a tail, and a wing for the forty-foot beast. Department head Danny Lee demonstrates a small-scale prototype of the tail mechanism for shop craftsman Harry Shepherd.

image

The formidable dragon leg under construction at the Disney studios.

image

ILM’s Phil Tippett devised the coloring for Vermithrax Pejorative and personally supervised the painting of the full-scale props at Pinewood.

was the stabilizer. That was the basic anatomical plan, although in most of its details it does not resemble a rhamphorhynchus at all. David did it so we would have a dragon which would look magnificent when it was flying, and was strange and horrible when it was clumping around in its cave.”

Bunnett began his research. “I did a lot of looking around at dragon literature. It was interesting but ultimately basically useless stuff. I found that dragons, as shown in the old pictures, were just plain goofy. Or else they would be very nicely done, but done by a sculptor or painter to fulfill the function needed by the art piece that was under way — basically a one-purpose dragon. If the dragon were shown in the air, for example, it would look very nice; but there would be no explanation of what this dragon does when it’s not in the air. Or, if it were shown on the ground, it would be this amazing ferocious thing, and it would have little bitty bumblebee wings and bright butterfly colors. You just knew that that would never fly, ever.”

Bunnett drew sketch after sketch. Working with Robbins he slowly narrowed down the essence of the dragon. For a long time, the head design eluded him. “That’s really where the personality is expressed to a great degree, and that was a tough one. We went round and round on that, and we seemed to alternate between too plain, nothing-going-on-here, and ridiculous rococo ornaments flopping all over the place. But one Saturday afternoon, as I was watching football on TV with my little sketchpad on my knee, suddenly I just came up with an idea which was the solution to the dragon. It was the bony ridge over the eyes, sort of sweeping back over the temples and becoming the horns. That turned out to be the motif that made everything else work.”

Bunnett also spent some time exploring what makes for a scary mouth. He wanted the dragon to tap the primal fear felt at the sight of a rattlesnake poised to strike. “I came to realize that you had to construct the jaw similar to a snake’s jaw. If you have a simple hinge with one pivot point, and you open the mouth wide, it just looks like a duck. What has to happen is it has to first of all develop some height at the back of the mouth, and secondly the lower jaw has to move back. Otherwise, it just won’t have it.”

Once the dragon was approved on paper, it was time to translate it into three dimensions. Bunnett, who had never before done sculpture, tackled the job himself and found it quite to his liking. Completed and approved, the clay prototype was turned over to Industrial Light and Magic where a modified and refined rendering was sculpted by Phil Tippett. “My whole objective,” Tippett explained, “was to take their basic notion of a long-necked, long-tailed quadruped, and make it serviceable as a stop-motion puppet. And I did that mainly by making necessary aesthetic changes in musculature, relation of body parts, and overall scale consistency that a real forty-foot animal would have.”

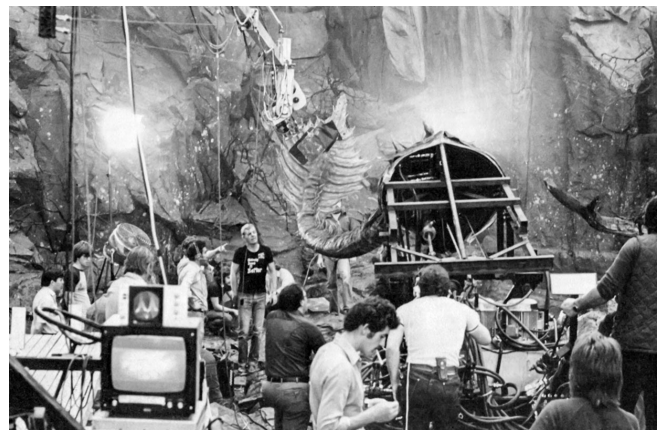
“Dave Bunnett was not a trained sculptor,” Hal Barwood elaborated, “so the dragon he produced, while very good, was really more on the order of a sketch. Phil Tippett resisted our original concept at first, because he thought it would be too difficult to animate; but once he accepted it, it was really he who turned it into a finished piece of art. His dragon was perfectly textured, with just the right surface detail and scale size and everything. And he did a lot of work on the head. The head itself was compressed laterally so it was taller and longer, and the eyebrow ridges had just the right articulation. You could still look at it and say, ‘Yes, that’s Dave Bunnett’s dragon,’ but there were a lot

of subtle refinements. In one stroke, Phil had solved the overall personality of the head and given it a kind of noble quality to go with its nasty disposition.”

An unexpected turn of events suddenly provided a source for the full-scale dragon props which were to play a significant role in the live-action photography. Without announcing their intent to either Barwood or Robbins, Paramount struck a *Dragonslayer* co-production deal with Walt Disney Productions — and with that, the impressive Disney special effects shop, headed by Danny Lee, became available. (At Disney alone, Lee’s effects career covers some fifty films — from *The Shaggy Dog*, to the Oscar-winning *Bedknobs and Broomsticks*, to the shenanigans of Herbie, the hyperactive Volkswagen.) Although other possible sources were investigated, it soon became clear that Lee’s facility had the edge in full-scale monster building. However, only a scant three months remained by the time they were given the go-ahead.



The dragon’s first appearance in the film was effected almost entirely with the fullsize props. Sacrificial victim Yolande Palfrey cringes as the dragon’s claw reaches out toward her.



The hydraulically-operated foot was mounted on a cage, from which studio technicians could operate the actuating mechanisms, and suspended over the lair set by means of a large industrial crane. Overhead scrims were used to diffuse the stage lighting so as to duplicate the overcast conditions encountered on location in Wales.

Phil Tippett's finalized dragon sculpture was shipped down to Disney, where it was then up to Lee and his staff to scale it up and engineer the internal workings. Barwood and Robbins felt strongly that even minute alterations would detract from the dragon's effectiveness, so Tippett, miniature set designer Dave Carson, and Jon Berg took turns shuttling back and forth, working with the Disney sculptors to ensure that subtleties in the dragon's design survived the transition to full scale.

The script described a beast forty feet long with a ninety-foot wingspan. That made for some pretty hefty props: a sixteen-foot head and neck; a twenty-foot tail; an arm-and-wing; and a huge claw. (The design of the claw, incidentally, proved rather straightforward. "It was a big beast," Barwood explained, "but it had to be able to fly. So it needed to be very lightweight, like a bird — which wouldn't be that unusual since reptiles are sort of related to birds, through the dinosaurs. Phil went out and got a chicken foot and we made a model of it and blew that up. So that's literally the dragon's foot — a gigantic chicken foot.")

From the outset, Danny Lee was somewhat concerned about the sheer size of the dragon parts. "That was something that was hard for Barwood and Robbins to accept, that this thing was *tremendous*. And to suspend it out and try to make it do what they wanted it to do in its full size was going to be real tough — especially the wing. Finally, I said: 'You look at that wall back there. That wing is as big as that wall. You'll never be able to handle it!'" Ultimately, the wing was built with a full-sized arm but a truncated finger/membrane section. As it turned out, however, it was used only as part of the dead dragon at the end of the film.

Full-sized clay sculptures were made for each part, but these served only to make molds for casting the dragon's skin, which would then be applied to the mechanical armatures. The armatures were complex, since many specific movements were required of the props. The head's eyes blinked and moved, its mouth worked, and the head and neck could move independently. The claw could grab a person. The tail could curl itself around.



The stage crew prepares for a shot involving the giant tail. The camera, affixed to the boom arm of Nick Allder's HALO crane, can be seen entering the top of the frame. Camera movements could be remotely controlled and the results observed on the foreground video monitor.

When the molds were ready, a separate casting step was made to make sure the skins would fit the armatures. First, the inside of a mold was covered with a layer of clay about a quarter-inch thick. Of course, this blotted out the mold's skin detail, but that didn't matter for this step. Now the mold was used to cast a thin fiberglass shell, the shell coming out the correct size and shape minus the quarter inch. The shell was then sliced into sections, like bologna, and used to encase the armature, making the whole thing look rather like a segmented worm. This was covered with a thin layer of foam rubber to help prevent wrinkling as the sections moved. Next, the clay was cleaned out of the mold, and the urethane skin cast. This technique ensured a glove-like fit.

While the Disney staff raced to meet their deadline, Elliot Scott's sets were rising on the stages at Pinewood. The exterior dragon lair set was built in the giant "007" stage (built to house the submarine bays in *The Spy Who Loved Me*). The existing water tanks were filled with scaffolding and the set was built over top, ten feet off the floor. This allowed room beneath for the dragon to come up through its crevasse entrance, and for the hydraulics needed to cause the earthquake which precedes the dragon's incineration of the Christian monk, Brother Jacopus. Casts were taken of Welsh rock faces to ensure their accurate reproduction in the sets, which also featured several tons of genuine slate lugged back from the exterior locations in Wales. The upper perimeter was constructed from immense (12x16-foot) blocks of carved styrofoam.

Scott's most dazzling set was the subterranean *Lake of Fire* where Galen (Peter MacNicol) first confronts the dragon. As big as the set was, Scott made it appear even larger by using forced perspective, and by placing mirrors at strategic places to pick up light from the fires, making it look as though large passages ran off the main chamber. The "burning water" in the lake was flammable gas. It was originally thought that the underwater gas jets would have to be moved in order to get the fire to spread across the water; but it turned out that if the gas was simply allowed to bubble to the surface unignited, it would spread across on its own until it contacted an already-burning source, then ignite and race back in a blooming sheet of flame.

The rugged, fractured, even dangerous surface of the cave and lair set floors made conventional dolly track construction impractical — but Matthew Robbins is particularly fond of a moving camera. An ideal solution to such a problem would have been to secure the services of a Louma crane, but even renting one for *Dragonslayer's* protracted shooting schedule would have been prohibitively expensive. So instead, the construction of a special custom crane was contracted out to effects technician Nick Allder, who produced a workable prototype in nine weeks and provided it to the company for half the cost of renting a Louma. Dubbed the HALO crane, it consists of a moveable 34-foot boom with a remote-controlled camera on the end. The camera operator and dolly grips do everything from the base of the crane, watching TV monitors which show them the film camera's view. No one rides up where the camera is, so the boom can be much lighter — therefore longer and more easily controlled. Thus configured, the HALO crane allowed for a wide variety of truck, dolly, and crane moves — all from one spot. When it was necessary to move the whole unit, it was simply picked up with the huge industrial crane which was on hand to move the full-scale dragon props.

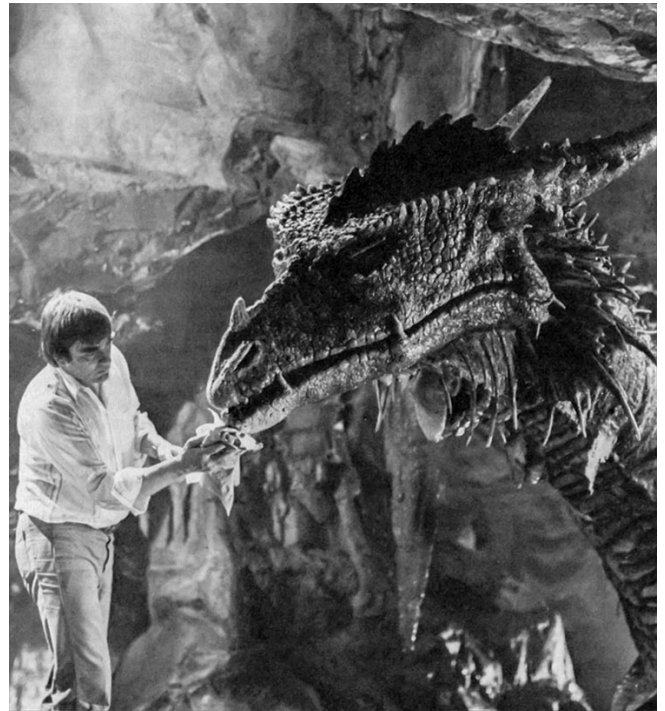
Those props were about five times heavier than the filmmakers had expected (the head/neck alone weighed about four thousand pounds), and they proved to be monsters in more ways than one. The power needed to move them strained the hydraulic systems to their limits and beyond, and

breakdowns were frequent. Even seemingly simple shots were exceedingly difficult. In the *Lake of Fire*, Galen is seen from a high angle while the full-scale head rises through frame, dripping water, opening its mouth. Thirteen people were needed to operate the head for that shot, which literally took days to get.

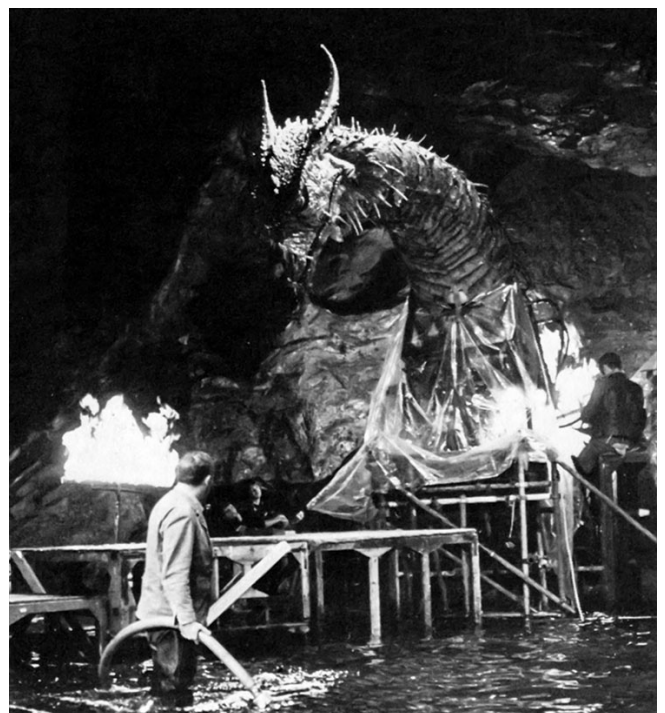
Many shots had been storyboarded for the props since, naturally, Robbins wanted to cover his action as well as possible during the live-action phase. “There were many occasions where months of planning and storyboarding were thrown out in a matter of moments when we’d discover that the hoses weren’t long enough to reach the part of the set where we want to shoot; or the pump was going to break and take three days to fix; or a joint would smash when we dropped the claw and it wouldn’t grab anymore. When you’re in production, you can’t stop. You *must* shoot something and you must shoot it right now, or you’ll never get it. So the level of frustration was extremely high.”

At the time, two things were done to help mitigate the production time being lost to the dragon props. First, setups on most of the dragon shots were given over to second unit director Peter MacDonald, since his smaller unit could operate much more cheaply. Robbins would discuss his concept for the scene with MacDonald, and then between setups with the first unit, he would bicycle back and forth to the neighboring stages to check on the dragon’s progress, coming over to direct only when a shot was fully set up.

Delegating work to the second unit relieved some but not all of the mounting pressure, and Robbins came up with a second idea. It occurred to him that for many shots he did not need all the various movements that the head could provide. Danny Lee had sent along an additional set of skins, so the decision was made to construct a lighter, simpler dragon head, which came to be known as the “B” head. “We had a brilliant styrofoam sculptor named Derek Howarth,” Barwood related. “Instead of building a lot of things out of plaster, or carving them from wood, Derek would just whip them out of styrofoam like crazy. He and Brian Muir did the ‘B’



Brian Johnson, supervisor of special mechanical effects, was charged with making the full-size dragon props perform as directed — a tasking which ultimately proved frustratingly impossible.



head.” Weighing only a hundred and fifty pounds, rigged on a teeterboard so it could go up and down, and bearing simple mechanical controls to tilt its head slightly, the “B” head saved much time. In fact, it is the “B” head that rises from the *Lake of Fire* directly behind Galen just before he turns around; and it is the “B” head that confronts the unfortunate Brother Jacopus.

~~The early efforts of this type of effect were made in the studio, but through the efforts of the studio, the effect could not be satisfactorily reproduced on the stage. As a result, streams of fire had to be photographed separately and then optically composited with the dragon.~~

Not all the stage photography was nightmarish. In fact, one of the more satisfying effects in the film was one of the simplest to achieve. In several shots, Galen is seen crouched behind his shield while the dragon’s fire rages around him. Some of these were actually done in the stage camera. “It’s the oldest trick in the book,” Robbins admitted, “double exposure. We locked the shield off, and we put the boy behind it reacting and cowering. Then we wound the film back in the camera, took the boy out, and shot the flame.” (Other shots were done using a fixed miniature Galen behind a miniature shield.)

The dragon’s fiery breath was quite real, a product of two flame-throwers designed by Brian Johnson. Both used a gas under very high pressure, laced with lycopodium powder to make it burn hot and bright. The larger, swivel-mounted and near cannon-sized, was used in the spectacular wide shot in the *Lake of Fire*, and later when the airborne dragon blasts the wizard Ulrich (Ralph Richardson). The smaller version was used for closer shots where the devastating reach of the larger wasn’t needed. Needless to say, the sets were scrupulously fireproofed.

In contrast to the problems with the adult dragon, the shooting of the dragon babies proceeded virtually without mishap. They were life-sized puppets which had been built at ILM by Ken Ralston, Chris Walas, and Dave Carson, and the only problems encountered with them occurred during the design phase when a basic law of nature had to be overcome. “The essential problem with the babies,” David Bunnnett observed, “was that the baby of *any* species is cute and adorable.” Since Galen was to summarily slaughter the little devils, it was imperative that they break this law. A number of designs were considered and rejected. “We had one,” Barwood recalled, “that looked like an eagle chick — tiny little flappy wings. You couldn’t even use it on Saturday morning television it was so cute.” Determining that large eyes were one sure-fire empathy-getter, Bunnnett did some initial sketches of beady-eyed babies. Eventually, Ken Ralston came up with the final, suitably repulsive look, adding long spidery arms and “a lot of bulldog and bat in the face.” Though the details are barely visible in the dim cave scenes, the babies also sport budding portions of the adult anatomy: stubby horns, tadpole tails, and rudimentary wing membranes.

Ralston and Jon Berg hustled the babies — three in all — to England. For simpler shots, Ralston operated a puppet himself. For more complex shots, he was aided by four professional puppeteers, hired locally. The babies were operated from beneath, through holes in the cave set floor. The puppeteers had video monitors with which to watch their puppets’ actions, and Jon Berg served above as spotter and general trouble-shooter.

Operating the babies was messy work. Fake blood, and the slime used to make their skin glisten, oozed through the holes and covered the puppeteers. Ralston’s only real complaint however,

concerned a scheduling problem. “One of the dumber things that happened, but just the way it happens in film — Dave Carson had rigged this thing so the eyes would blink; we had balloons all over to swell things on him and move all over the place. So what do they schedule first? — the scene where Galen is tearing these creatures to pieces in the cave. The eye blink isn’t in the show at all because one of the first shots was Galen hitting this thing with the torch — which wasn’t planned — and he hit it *square* on the top of the head, which broke the mechanism. I remember sitting under there getting my hand beat to pieces and looking at the video after he had done it. The eyes were just hanging out; the mechanisms, springs, everything was destroyed; the balloons in the throat had broken. He was even *burnt*, because of the torch. Then I had like three weeks to get them ready for the earlier shots where Valerian (Caitlin Clarke) goes down into the cavern and sees them.”

Phil Tippett and Dennis Muren also made the trek to Pinewood. “The issue of the dragon’s color wasn’t really addressed until I got to England,” said Tippett. “Amidst a hectic shooting schedule and hiring puppeteers for Ken and Jon to work with, I was lucky to pull Matt away from the set for a minute or two to confer on what colors should be used to integrate the dragon into the cave sets. I felt it was important to make the dragon look as though it was part of its world; so I would walk to the stages, pick up handfuls of slate and rock, and then go back to the painting area and derive some similar colors.” Once a color scheme had been approved, Tippett personally supervised the painting of the full-size dragon props before returning to California.

Dennis Muren’s activities were more directly related to the work that would later be done at ILM. While at Pinewood, he gathered up film clips, reference

photos, set pieces, and anything else he could find that would help match the effects to the live-action. This was something that had not been done on *The Empire Strikes Back*, which caused problems when it came time to do the walker battle sequence. While at Pinewood, Muren also worked out how all the ILM shots were to be done and what plates would be needed. The fact that much of the live-action was being shot in smoke environments caused him much concern, and in some instances he shot two or more plates of the same action but with different smoke levels. “Hal and Matt were totally cooperative with my requests,” he said, “even if it meant some additional time on the stage with the crew and actors. Ten minutes more on stage might save days later at ILM.”

When footage of the full-scale head began coming into ILM, reaction was less than enthusiastic. The dragon *looked* terrific, but it didn’t move well. “The guys that worked the dragonettes, the babies,” Dennis Muren theorized, “were experienced in performing with puppets and projecting their thoughts into those puppets. But the guys that were trying to work the big dragon were laborers, not puppeteers. Also, I think maybe it could have worked better than it did, if they had put

image

Ken Ralston prepares to paint the baby dragons — including a decapitated version — which were produced at ILM and shipped to Pinewood for main unit photography.

image

Jon Berg, who served as trouble-shooter during the baby dragon photography, holds one of his unruly charges. Since the infants of any species are almost invariably cute, considerable pains were taken to make the nasty little creatures as unappealing as possible.

image

Galen (Peter MacNicol) battles one of the baby dragons, which were Muppet-type creations manipulated from beneath the stage by Ken Ralston and a team of British puppeteers.

some guys on it to work the bugs out. As it was, it just got rolled onto the set and was expected to work the first day — to act the first day, not just work.” Nevertheless, the storyboard demanded many dragon closeups, and it was obvious that the full-scale head simply was not going to provide them. The solution was going to have to come from ILM. (Complicating matters in postproduction was the fact that the first cut of the film was two hours and forty-nine minutes. As it was drastically pared down — by a full hour — the ongoing changes inevitably affected the storyboarded effects sequences, causing considerable confusion in all departments.)

In mid-production, Hal Barwood flew back to northern California to work out a solution with the fantasy specialists at ILM. Ultimately, it was to come from Chris Walas in the form of an ingeniously devised hand puppet. The idea had been broached much earlier, during preproduction, but concern over possible matte lines and intercutting problems had prompted Matthew Robbins to push for the elaborately articulate Vermithrax which he could “direct” on the stage. At this point, however, earlier concerns seemed less pressing. Chris Walas insisted he could build a workable puppet, and Dennis Muren was confident it could be photographed convincingly. Barwood okayed the idea, and Walas went to work on a half-scale “closeup” dragon, which could be set up and shot entirely at ILM.

For basic moves, the closeup dragon was operated simply by sticking one’s arm up the neck and grasping a pistol-grip control mechanism within the head. It also featured a number of cable-operated mechanical functions controlled externally by assistants using levers fashioned by engineer Stuart Ziff. Each lever was topped with a standard motorcycle control handle so that two functions could be performed at once by pulling the lever and twisting the handle. The closeup dragon’s repertoire was substantial. “Most of the functions were not originally designed into the dragon,” explained Walas. “It was a reptile and reptiles don’t have a lot of facial mobility. So it was very difficult just deciding what to make move and to get it to move convincingly. It had the brows raising and lowering, the eyes moving back and forth, the eyelids opening and closing. The bridge of the nose sort of wrinkles up. The nostrils open and close. It snarls — they sort of insisted on ‘snarls’ — very unnatural move. The temples pulse. The tongue swells in the throat.”

Almost none of its functions are evident in the film, but the closeup dragon was indispensable nonetheless. For the most part, it was filmed “live” against miniature cave settings. The job of setting up and photographing these new shots was given to cameraman Rick Fichter, who had already spent six months in England and on location with the live-action unit, representing ILM and maintaining its VistaVision equipment. Having spent weeks in smoke-filled cave sets watching Derek Vanlint and Peter MacDonald fight the numerous lighting problems which occurred while shooting in smoke at very low light levels, Fichter was an ideal candidate to try and maintain shot-to-shot continuity between the live-action footage and ILM’s miniature inserts. Working with a small, skilled stage crew, Fichter was able to set up and shoot all the required closeup shots in a matter of a few weeks.

Since most of the head shots could be cut directly into the film, they were photographed in four-perforation anamorphic format rather than VistaVision. And generally they were filmed in slow motion — between 32 and 48 frames per second — to help give a sense of mass. Usually Chris Walas had three assistants to help operate the head, although sometimes as many as six were needed. Working in slow motion made orchestrating the dragon’s movements rather confusing. “We

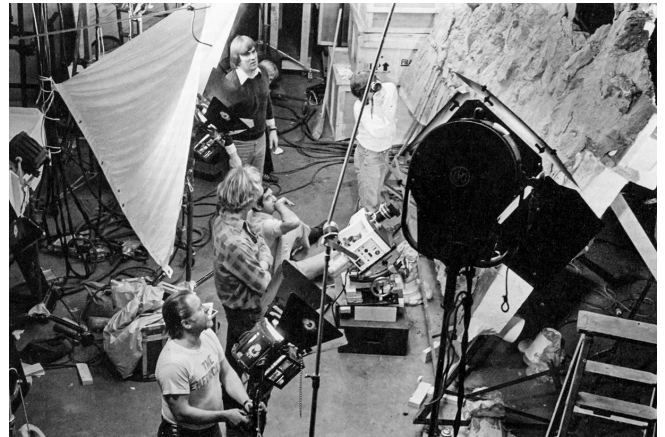
carefully went over what it was going to do in each shot,” said Walas. “And it was very difficult because we wound up having to do it in half the time or three-quarters of the time it was actually supposed to take. So what we finally wound up doing was going over it in real-time, and then counting it off as we went — which tended to work pretty well.”

The closeup dragon had the subtlety of motion lacking in the full-scale head, and Robbins — who even directed a number of the shots himself — was delighted with it. As a result, it was used to considerable effect throughout the film, including the scene of the dragon nuzzling its dead baby (a special half-sized version made up by Ken Ralston to be extra-floppy and dead-looking). In one interesting shot, during the cave battle, the dragon head snakes directly toward camera out of the darkness, creating the impression that the rest of the dragon is behind, but in deep shadow. In fact, it was simply Chris Walas standing there draped in black. The shot happened to be Walas’ favorite. “That’s what I thought the puppet should have a lot more of — just a lot of movement. But part of the problem was that most of the closeup shots, or a fair amount of them, had to match flame shots. So we didn’t have a lot of leeway for movement.”

The need for the closeup dragon actually arose rather late in the game. Long before that problem came up, the ILM team had been wrestling with their biggest challenge — how to deal with the dragon as an animation puppet.

From the beginning, Robbins and Barwood had assumed that dimensional animation would be the way to go, and had simply hoped that ILM would do the best possible dimensional animation. But as their dragon design solidified, it began causing real consternation in the ILM camp. “Phil was petrified about animating the dragon that we had,” Barwood recalled, “so he kept proposing these dragons which were very rotund and tended to sort of lie on the ground a lot, so that when they moved they wouldn’t have to be too articulate.”

“The design was so peculiar,” Tippet explained, “that it was very difficult to touch — especially the way the wings folded and covered up a lot of the body. As a practical stop-motion puppet it was a very difficult hands-on sort of thing. That was one of the first reasons we started thinking we’d have to come up with another way of articulating this thing. And we figured that there must be a way of adapting motion control equipment that was available at this facility to plug into a pretty standard stop-motion puppet.”



Since the miniature avalanche set built at Pinewood had failed to fall convincingly, a second one was built by Lorne Peterson and his miniatures crew at ILM. Brian Johnson (top center) supervised the high-speed photography, which was shot by Bruce Hill (on floor) using his 360 frames-per-second camera.

image

In an early test of the motion control dragon mover, Phil Tippet animates one of the walking dragon armatures while system designer Stuart Ziff monitors the computer console. Although the dragon mover is actually controlled by the animator, the console operator handles the recording process and can manipulate the recorded actions by shortening or lengthening the cycling time, or by adding or subtracting parts of a move. During production, the console was operated by Gary Leo and Bess Wiley.

Achieving this end would require a number of breakthroughs — not just in hardware, but in thinking. And the thinking ranged far and wide. “It had always been floating in the air that we were ready to try something like this,” said Dennis Muren. “We were talking about whether we wanted to do a major film with stop motion, which didn’t seem like it was doing anything new. One of the things I’d thought of was trying to do it with muppets, where you have a rod puppet sort of thing — shot bluescreen but done live. That wouldn’t have worked either because you would have had five guys trying to make this thing look alive. They never could have synched up.”

Engineer Stuart Ziff joined the team to tackle the problem from the motion control point of view. “It was obvious that the puppet was just too small to put any motors inside. Not knowing exactly how we wanted it to move, we came up with the idea that whatever it would be would connect externally. Since the dragon would usually be photographed so it was dark, we could conceal rods coming up to the feet.”

This was the sort of sidestep logic Muren had been looking for. “What had kept the idea from being done before,” he explained, “was that everyone had thought that it had to be done internally, like the figures at Disneyland. But I saw *The Land That Time Forgot* — which was all rod puppets — and I thought there were moments in that stuff that worked. Not many, but in an eight-second cut that was terrible, there might be two seconds in there that worked. You see little clues like that and you say, ‘Maybe that’s the way to do it.’ Not to wait till some sort of incredible technology is available in 2050, but try it right now — just do it and see how it works.”

While Stuart Ziff set to work devising a motion control mechanism that could effectively move a miniature dragon, Phil Tippett was busy with effects production coordinator Laurie Vermont trying to locate all available 16mm footage of walking lizards. “The look of the dragon was very much wrapped up in how the thing should move,” Tippett explained, “so I dissected the 16mm lizards and compiled pages of notes. The whole crew would go into the projection room and discuss everything from abstract kinetic motion to the psychology of an animal’s movement. Tom St. Amand might see something that would give him a clue on how to build the armature and allow it to make a variety of interesting moves. Dennis might notice something about the personality of a creature that added to its characters. That’s how we approach most situations — pulling in perceptions from all involved. Then Dennis, Stuart, Jerry Jeffress, and I would have long meetings about complex electronic equipment and how dragons walked. Stuart and I would mock-up rough setups and apply what was learned studying the film with the peculiar arm/ wing configuration that Tom St. Amand and Jon Berg were figuring out how to armature. What we all wanted was to break away from the stereotypical stop-motion look, which is not only an artifact of a succession of still photographs, but a simplified geometry in the blocking out of the shots that some animators are forced to do.”

After some six months of coordinated effort, Stuart Ziff’s dragon mover was unveiled. In its final form, it looked, loosely speaking, like a blocky mechanical elephant lying on its back with legs upstretched. Each “leg” was actually a separate unit; and each unit was driven by three stepper motors which, through a seeming maze of chains, gears and pulleys, allowed the unit to move in all three planes. There were six such units: one for each dragon leg, and two extra — one to move the dragon’s body, and the other later used to drive the head and neck. The entire six-unit complex rode

on a motion controlled cart which had eight feet of travel on a track. Of nineteen stop-motion motors included on the rig, sixteen could be under motion control at any one time. In use, the dragon was perched above this contraption, connected to each of the units by rods and, in effect, riding along in midair.

This was a far cry from the work that had been done with the running tauntauns in *The Empire Strikes Back*. There, only the gross body movement of the tauntaun had been under motion control, and then only in two planes (forward-reverse and up-down). All other animation on those puppets was done by hand, conventionally. Furthermore, since the most complex motion control spaceship move to date had required only nine motors, a new computer was needed to provide the sixteen channels of control. ILM electronics technician Gary Leo modified an Apple II to do the job.

Ziff deliberately designed the mover like an erector set in the sense that it could be dismantled and reconstructed in a wide variety of configurations, depending on the demands of the shot. The puppet armature featured threaded holes to accept the connecting rods. The rods, in turn, were attached to the motion units via a “plumbing system” of larger rods and clamps. This rod-clamp system provided even greater flexibility, so that the dragon could be set up to do virtually anything without rods crisscrossing or motion units colliding with one another. Ziff even provided for the use of three different sizes of motors. He had thought that the smallest (and weakest) motors would be adequate, but it turned out that the larger ones were necessary.

Ziff is steadfastly matter-of-fact about the creation. “You have to understand that the significance is that there is no significance. It’s no different from standard motion control except that we connect it to the puppet. The significance is that we got it working.” Actually, he does admit to one difference between the dragon mover and other motion control setups. The mover has one-to-one gearing (instead of the industry standard of having very low gearing, requiring motors to make many revolutions for moves of small distances). This meant that the dragon could be moved at real-time speeds, if necessary; and this was due to new circuitry designed in Jerry Jeffress’ electronics department. “The circuitry that Jerry’s people came up with made the stop-motion motors turn one-3600th of a revolution — a tenth of a degree — per pulse. Obviously, you give the motor many pulses in the course of a move. The important thing is, when you can break something into a lot of increments, it can be very, very smooth.” As it turned out, though, it was never practical to put the dragon through its paces in real-time, but Ziff is a chronic over-designer, as are most engineers who work in film. “It’s my experience that I’m not really making it for the final film. I’m making it for the people who employ me at the moment. If it looks good in dailies, they let it be known; and the fact that they don’t use it in the film — they don’t even care about that. My philosophy is, you use their money, and when it’s all done and it works, they don’t ask questions. But if they’re spending three thousand dollars an hour on the set, and you say: ‘Hey, listen, I saved you twenty-nine bucks and that’s why it doesn’t work now’ — they don’t want to hear it.”

The concept of doing full-blown motion control animation was not entered upon without some trepidation. No one was sure exactly how it would work, or even how it would look. It was, after all, mechanical. Would it look that way? If the system flopped, the only recourse would be to fall back on conventional stop-motion animation, running two setups simultaneously in an attempt to meet the production deadline. Barwood voiced the tension everyone felt: “We had to spend months constructing the dragon mover, and we had to spend more months learning to use it. We were all

chewing our nails by the time we started getting our first walker shots (January 1981). Eventually, though, we *added* some, because it became obvious that they were *great*.”

As Barwood indicated, tremendous effort was expended before the first walking dragon shot could be done. First of all, a puppet had to be built to suit the system. Though they had accepted the basic dragon, the ILM team still felt that two structural changes were needed. “One feature of the original design,” said David Bunnett, “which is different from the final one is that the original was much more gaunt and ragged. But when you have to have a model that moves, you have to limit yourself; because if you have a design that exposes the musculature to a substantial degree, it’ll look fine when it’s stable, but when you see it moving you’re going to expect to see those muscles do things. So they had to sort of smooth it out a little bit. The other area was the wings. The wings look like bat wings magnified ten thousand times; and it’s a good look — in fact, I think it’s excellent. But initially, I wanted to have a wing which was a little bit more reptilian. In my mind it would be a leathery expanse that would have cartilage sort of struts or something. But the people who had to manipulate it on camera felt that that was too difficult, and by going to a bat wing type design they had the obvious advantage of stiff finery things they could stretch a membrane between. So you have to keep in mind the difference between design and art. In design there are sort of irreducible problems that have got to be dealt with.”

The armature, too, had to be designed with the new technique in mind. Tom St. Amand began with ideas formulated by Jon Berg and Doug Beswick on *The Empire Strikes Back*. “For the legs and arms of the walking dragon, we built hinges and swivels so that Phil, in the midst of a shot, could lock off certain axes of movement. If the dragon had to walk in a straight line, obviously you wouldn’t want the legs to go cattywampus out. So with these you could lock off the joints which would make the legs do that.” Knowing which way the joints would go made life considerably easier for Phil Tippett. “The motions were all real positive,” he affirmed, “since they were based on single-axis swivel movement. We didn’t have to hassle with ball-and-socket drift.” (Only the neck and tail of the walking dragon were ball-and-socket jointed.) A second walking dragon armature was made, in anticipation of the possibility of needing two working

image

A finished flying dragon (left) serves as a model for the second, under construction. The larger, walking dragon is a prototype that was used for various purposes, including the testing of different types of skins.

image

The walking dragon, mounted on the mover, is programmed by animator Phil Tippett. Behind and above it is a miniature set piece built by Dave Carson (blurred in frame), with a scrim positioned in front of it to impart a sense of aerial perspective.

image

A full animation setup. The dragon is mounted on the mover in front of a miniature setting augmented with scrims. To allow maximum mobility for the dragon mover and animator, lighting is suspended from overhead pipe rigging. A small video camera is positioned above the VistaVision stage camera so that moves can be recorded and previewed on the Eigen video animation system at left.

image

Dave Carson applies finishing touches to one of his miniature set pieces.

image

The dragon, mounted on the mover, is held in position and activated by a series of external rods connected to motion control stepper motors.

simultaneously, but the armature was used only as a prototype for trying out dragon skins and other testing. Two four-inch human armatures were also made, for the puppets which would represent Galen in the cave battle.

Since joint tension would have to be adjusted constantly, the armature was carefully diagrammed, with all wrench sizes noted. Then, when necessary, Tippett could use the diagram to locate a particular joint and cut into the puppet precisely at that point. In fact, by the time the filming was completed, the dragon had dozens of invisible access cuts all over its body.

Since Tippett had to be in England to supervise the painting of the full-scale dragon props, it was actually Chris Walas who did much of the preliminary work for constructing the puppet. “I started sculpting the pieces for the walking dragon, which was done in many little sections. Fortunately, Phil came back in time to supervise me on that, because I wasn’t used to doing small models, and so I wasn’t familiar with working with that type of detail. I sculpted the head, the body form, all the little tail frills and gills and feet and claws and spines on the back and things like that. I also made up most of the molds and did most of the casting. Then Phil wound up doing the vast majority of the final fabrication, putting all the pieces together and adding the skins.”

When puppet, mover, computer, and crew all came together for the first time, the plan called for the dragon to have a hybrid motion, with the mover controlling the feet and body while Tippett animated the head and neck conventionally. This approach was predicated on the fact that the dragon was to be filmed in Dave Carson’s miniature sets. Dragon mover rods coming up to the feet and body could be hidden in shadow or behind foreground rocks, but a rod running to the head was another matter. “We couldn’t figure out how to motorize the neck and head without doing everything bluescreen,” Dennis Muren explained, “and we didn’t want to do everything bluescreen. So the first shot Phil tried was when the mother walks out and looks at the baby dragon. Doing everything he could to focus attention on the head and neck — which is the only part that was just stop-motion — it still showed up as looking different from the rest of the puppet. In fact, it was perhaps *more* objectionable than if the whole puppet had been stop-motion. And this was the full miniature set, with scrims in there for smoke and all sorts of stuff. It was so complicated that we figured: ‘What’s the point of doing every shot like this when it’s a compromise. What we want to do is motorize that head.’ That was when the

image

Galen confronts Vermithrax in the underground Lake of Fire.



Articulate rotoscope mattes were produced by the ILM animation department whenever fire had to appear to be coming from within the dragon’s mouth. Meticulous frame-to-frame tracing around the mouth and teeth was needed to produce mattes which selectively masked out unwanted portions of the flame and faithfully followed any movement of the dragon’s head. Residual smoke was

decision was made to motorize the head and shoot the stuff bluescreen.”

~~The dragon's design by David Burnett and Phil Tippett department helped accentuate the creature's grace in the air and its ungainliness on the ground.~~
photographed separately and added by the optical department.

Thus, almost all of the twenty-odd walking dragon shots in the cave sequence are bluescreen traveling matte shots, with the dragon matted into miniature cave settings photographed separately. Shooting the dragon in a bluescreen environment allowed the rods to be hidden either by masking them with blue pylons (small plastic rods lit from within to match the color of the blue screen) or by rotoscoping and creating articulate mattes to blot out the rods. (Generally, only the rod controlling the head required rotoscoping. Attempts to cover that rod with a blue pylon failed because the blue light reflected off the dragon's shiny skin, creating drop-outs in the dragon's matte.)

Setups were almost indescribably complex when compared with conventional animation. First, the basic configuration of the mover had to be determined. ILM cameraman Mike McAlister was particularly useful in this regard, since his engineering background allowed him to quickly build rigs which were necessary to hold the motors in all sorts of odd positions. Then the attaching rod system had to be built up. Even if the shot was bluescreen, the arrangement had to work in such a way that the rods did not pass in front of the puppet's own body during the movement. Camera position was critical. Often, alignment of all the paraphernalia was so precise that camera movement of an inch in any direction picked up some flaw in the shot.

Interestingly, in the shots with the dragon in miniature settings, the rods were not always completely hidden. In one case, where the dragon was coming over a rise with a light background behind him, Tippett moved the tail over in order to keep a dark shape behind an exposed rod running to the hind foot. But such tricks were not always possible, or necessary. “There are some shots,” Dave Carson commented, “where you *do* see the rods coming out of the back feet, but there are so many spines from his wing, and he is so often silhouetted — at least from the arms back — that when you do see a rod, there's just so many other spiky things going on back there that it doesn't reveal itself as such.”

With mover configured, dragon in place and shot aligned, there was still programming to be done. One phase of that was selectively tightening and loosening joints so that the puppet would respond appropriately to the rod movement. Then the sixteen separate memory tracks were built up, one at a time. With three motors per unit, and three tracks per limb, programming was no simple matter. “It was complicated,”

Ziff pointed out, “because each foot could go up and down, and back and forth, and right and left, but when you had to go in a circular motion — you could only program one track at a time — it was like working an Etch-A-Sketch with one hand and trying to get it to look circular. That was sort of difficult, but Phil mastered it.”

Another thing to consider was the fact that all the motion units rode together on the one cart. Therefore, as the dragon walked forward, to get a given foot to appear to stop on the ground while the body continued to move, the foot's unit actually had to be programmed to move backward at the same rate the dragon moved forward. Initially, Tippett did this by hand, but later Gary Leo devised a program enabling the computer to do it. Even so, programming this multi-limbed creature was far more involved than programming the flight of a miniature spaceship, which at least responds as a

single unit. The simplest walking dragon shot took a day to program. Most took longer. “We started off with some of the more complicated shots,” Tippett recalled. “They would take anywhere from a week to two weeks to program. Some of them, where the dragon was moving very quickly — such as the shot where Galen jumps on the back of the dragon and it’s trying to buck him off— took about two and a half weeks to program. Then it took about an hour to actually shoot the cut that was ultimately in the film. By the time we got most of the very complicated shots out of the way — which took about two months — we were able to finish up the final third of the shots in about two and a half weeks because we’d gotten so familiar with the system.

“It was very much like a musical group or something, because we invented this entire system of talking in numbers back and forth, and talking about different motors. It took a lot of concentrated effort, focusing for extended periods of time on what we were doing, standing in the same place sometimes for twelve hours and just working this thing through until we got an adequate movement out of the dragon. We checked all of our movements with a video animation system that really facilitated our understanding of what we were doing right then and there, rather than having to shoot a test roll of film and wait for it to come back the next day. We could program one track, shoot it, see how that was going, try it at a number of different speeds, and from that build up successive tracks. We had to break down the most gross axis of movement first, then add the lesser axes on top. A number of times what would happen in the beginning, when we were unfamiliar with the system, was that we’d spend a week programming something and get locked into a movement that didn’t work properly and was real hard to get out of. So we’d just have to throw everything out and start over again.”

Even with head, feet and body motorized, the dragon required some supplemental animation. But once a shot was programmed, this work, too, could proceed swiftly. “Since our lab run was at six o’clock every night, we were in a constant race for the deadline. There were a number of reasons why we had to do that, not only to check the final movement of the dragon, but just to make sure that Dennis’ setups and lighting all matched, and everything was married happily together. So what would happen is we would work and work and work up till about four or five o’clock, and then start shooting. It was literally a lickety-split pace —just a matter of putting your hands into frame, moving the puppet real quickly, pulling back down, and taking a frame. One of the major attributes of the walking dragon setups was, since these rods were plugged into all the various members, there wasn’t much necessity to gauge things with surface gauges. It was all pre-gauged and locked down. That really helped the continuity and the flow of the animation. All we



Before the lighting of the effluvia, each rod was stored in a hidden compartment at the rear of the stage, and was pulled out by a stagehand at the start of the performance. The rods were connected to the dragon's neck. In addition to the four motion controlled rods connected to the dragon's feet, two others were also employed — one on the body, and one on either the top or bottom of the head, depending on the shot. The foot and body rods were generally concealed with blue pylons which blended in with the background blue; but the head rod, for the most part, had to be eliminated with articulate roto mattes.

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Hal Barwood pointed out still another advantage: “It allows the animator to store his ideas, the way you’d write them down if you were writing a script. Then they get played back ensemble, as a sort of symphony of motion. I think that’s even more important than the jerkiness. The quality of acting is better, because poor Phil and Ken didn’t have to *remember* everything from frame to frame.”

Of course, go-motion wasn’t exactly a universal boon. Dave Carson admits it wasn’t much help to him in his miniature set design. “The problem with having the dragon in the set was that the sets could not be supported by gravity from below — they had to be suspended. And because lighting had to get in, the animator had to get in, and because the puppet was right in there, we were dealing with set *pieces*. It was impossible to actually construct a miniature cave. It had to be done in layers of facades. And unfortunately, we found in the first couple of shots that it *looked* like layers of facades. The biggest problem, constantly, was the fact that the dragon is so small. As a stop-motion puppet, he’s pretty good size — about three feet long — but he’s supposed to be like fifty feet long; so with the lenses we were using, the camera would be just right on him, and the set would be maybe two feet deep. That’s where the real problem came — trying to get everything in such a small area. Then it turned out that we ended up bluescreening the dragon in most of the shots. Had we known we were going to take that approach initially, I could have built the sets at a different scale. But we didn’t know we were going to bluescreen until we did.”

In general, for a bluescreen shot, the miniature set was photographed separately for use as a background plate, but occasionally Carson put small set pieces in the bluescreen setups. For example, when the dragon first leaves the Lake of Fire chamber, it grips the lower edge of a tunnel entrance, hauls itself into view, and blasts fire at Galen. This is a bluescreen shot, and all the cave area is a background plate save for two small pieces of “rock” that the dragon grabs to pull itself up. “I was very limited as to how much set I could get in there because there was rig just *everywhere*. So it was just two small pieces. There was part of a two-by-four behind each one so Phil could wood-screw down through the puppet’s hands once it made contact. Then they’d remain rigid there as the rest of the body came up.”

As it happens, one of the most striking shots in the cave sequence is one in which a full miniature set was used. Just after discovering the dead babies, the dragon comes down a smoke-filled tunnel, straight toward the camera, appearing to pass right through the smoke. The camera then tilts up to reveal the live-action Galen poised on a ledge above — projected, simply enough, onto a piece of white card placed in the set. “What you saw there,” affirmed Muren, “was what we saw through the camera. There was a beam-splitter in front of the camera and the smoke was a reflection of a back-lit opal glass or something that was painted in the

image

In the animated puppet’s first scene, Vermithrax rears back and glowers at Galen before letting loose with a stream of fire. In addition to the dragon mover mechanism, additional equipment (in foreground) regulated the amount of air pumped into the puppet to swell the chest and neck as it prepares to spew its fiery venom. A light inside the dragon’s mouth was attached to a rheostat so its intensity could be increased during the fire-breathing phase.

image

Effects supervisor Dennis Muren had the challenging task of matching all the miniature setups to the live-action stage photography.

image

Phil Tippett applies silicon to the dragon to make it look slimy and wet.

shape of the cave opening so the smoke didn't go beyond that foreground. The dragon was simply in the dark back there and walked up into the light. And in that case, the rod controlling the head went down under the dragon and below the set. Our original thought was to dim down the smoke element so it would look like the dragon was coming through, but that might have looked real funny if the smoke got dark as the dragon got light. As it turned out, it wasn't even necessary. Just walking it forward we could do it.

"We ended up having to do a second pass on the element of Galen up above because we were rushed, as always, and we didn't really have time to get the exposure and cut the contrast down enough on the projection. We had a low-contrast print, but when we ran wedges on it there was still too much contrast in it. And so Phil wouldn't have to go through and animate that whole second half of the shot — he was doing supplemental animation on that — we did it the first time with just a black circle up there the same shape. Our repeater system repeated it accurately enough so that Bruce Nicholson could work on that little miniature projection and cut the contrast down on it. Then we turned the projector on and had all the rest of the lights out, and just did a tilt-up with the best we could do on the exposure."

For the flying dragon, it had always been assumed that existing spaceship-type motion control techniques would be adequate, and this proved to be the case. Two flying dragons, somewhat smaller than the walker, were made with conventional ball-and-socket armatures. One of them, however, was fitted with another of Stuart Ziff's inventions, a tiny gearbox implanted in the chest to flap the wings. Barely an inch on a side, the tiny device was selected after available motors proved too large and hydraulics proved impractical. The gearbox was connected to external motors by thin, flexible drive shafts (one for each wing) which could enter the box (and puppet) from top, bottom, or rear, depending on the needs of the shot. With its motors under motion control, the mechanism could take the wings through any desired flap cycle. However, since it acted only on the dragon's forearms, it was still necessary to animate the wing tips by hand.

Ironically, however, Matthew Robbins would decide that he didn't want the dragon to flap its wings much, as flying-dragon animator Ken Ralston was to discover. "We came back from England (October 1980) and I got into the flying stuff real soon, just to get something on film so they could start seeing what the dragon was going to look like. Shooting it was basically the same as shooting the ships in *Empire* and *Star Wars*. Every shot I did was bluescreen, just using the Dykstraflex camera. I could program the basic moves, but I still had to go over there and animate it. But since the basic and broadest moves were done with the 'Flex, which was moving during exposure, you couldn't tell it was strobing very much. The first flying dragon I shot was not at all the way it ended up in the film. It was a slower, more serpentine thing; and there was much more flapping. So it was good that I started when I did, because as soon as Matt and Hal finally saw the dragon on film — something they'd been imagining ever since they started on the script — a lot of things changed. It turned out they wanted something that glided most of the time."

"We hadn't really had a chance to establish a working relationship with Ken and Phil," Robbins explained, "and the ideas as to the personality of the dragon were not really in hand. There was a shot of the dragon where I felt it was flapping its wings too much. Ken really thought it was very believable, but I just had to decide what I wanted to go with. The shot was, technically, as good as anything that was ever done; but in terms of the dramatic feel of the creature, I wanted something

very different. I wanted it to move with very little wing movement. The more it had to flap to stay airborne, the more it sort of seemed to be struggling. Flapping just did not seem to be in tune with its regal nature, and so we dropped that idea from many of the shots.”

In addition to soaring like a sailplane rather than flapping like a vulture, it was decided that the dragon, master of the air, should fly quite fast. “People have remarked on that,” Barwood commented. “All I can tell you is we had it flying slower in the beginning, and we threw out some elements that Ken made on that basis. One has to balance what one thinks external reality is like versus what drama is. And people who pay very close attention to their presumptions about what external reality is sometimes forget that the first requirement for a movie is drama. We know it’s going too fast. We did some math, and it’s doing around a hundred and fifty miles an hour most of the time. But we make no apology for that fact. Believe me, when it seems to be going the right speed, it looks altogether too languorous and relaxed to be able to generate the intensity you need at the end of the movie.”

Ralston adapted, and continued to crank out flying shots — more than forty in all. As time grew short, he and Tom St. Amand began double-shifting.

Ralston would set the shots up during the day, and St. Amand would come in at night to animate them. For the most part, manual animation was held to a minimum, and the bulk of Ralston’s effort went into programming the Dykstraflex camera movements.

“Some things were easy to program. We could shoot a whole bunch of different versions, and they would find something they liked. We’d change it a little bit, do different poses as it would fly. We didn’t gauge it that much. In fact, after a while, we got so into what the movement was that we really didn’t need a gauge at all. We pretty much knew what was going to work and what wasn’t.”

Other shots were not so easy, notably the shot of the dying, smoking dragon spiraling earthward toward a mountain lake matte painting. On the stage, Rick Fichter had photographed a descending smoke bomb fashioned by pyrotechnician Thaine Morris. Since the smoke element had to be shot live, it became Ralston’s task to match the dragon’s movement to whatever the smoke did. Once that was accomplished, Ralston did a separate pass on the dragon’s descent — repeated precisely via motion control — with the stage lights turned off and a small light attached to the dragon’s chest so it would appear to glow, adding visual validity to the dragon as source of the smoke. The effect was further enhanced in the animation department by Loring Doyle who animated embers flying off the dragon’s body.

One of Ralston’s most stunning shots is the dragon hovering awesomely, breathing fire on Ulrich during the final battle. “They shot a plate of Ulrich. Then they shot a flame pass with the set all dark. And the flame was moving up and down — it wasn’t just locked off — so I had to match the flame with the head. That was my favorite shot. Took forever — I think it was two weeks — countless

image

The essence of ILM’s “go-motion” system — Vermithrax thrashes about wildly, trying to dislodge Galen and his lance. With traditional stop-motion, no matter how fast the intended move, the animation puppet is frozen into a static position during each frame of exposure.

image

However, using motion control technology akin to that employed in flying miniature spaceships, ILM was able to impart a smooth, even blurred, movement to the animation puppet, which eliminated totally the strobing effect characteristic of much stop-motion work. Once a shot was programmed, the time required to actually shoot it — and reshoot with changes, if necessary — was minimal.

times to shoot. It was hard to have it do all these different things and still keep that head tracking with the flame. On that shot, too, we had the flapping mechanism hooked up, which meant that we had cables running out the back, so we had to bluescreen those out.”

Ralston also has the distinction of having done the only completely conventional stop-motion shot in the film — a long shot of the dragon perched on a rocky crag, moving its wings and glaring down at Ulrich, Galen, and Valerian, just prior to the final battle. There was some thought of doing the shot with the larger, more detailed walking puppet, but production pressures did not permit it; so Ralston did the shot with one of the flyers.

Except perhaps for that one shot, Matthew Robbins had an unprecedented amount of control over the puppet animation. “Since it was linked up with the computer,” Phil Tippett explained, “if the director saw that the puppet was moving too slowly, he could say, ‘Well, I want it to go faster.’ You’d shoot yourself if he told you that after you spent two days doing conventional animation. But this way, we just entered another value and could speed it up by almost any percentage he wanted.”

“It’s the only stop-motion film I can think of,” added Dave Carson, “where the director was able to treat the effects shots the same way that he treated the live-action. That caused us a lot of headaches and a lot of grumbling, but it’s the way most directors like to work.”

Indeed, that was exactly how Matthew Robbins liked to work. “The ILM team, with whom ultimately we had a very good working relationship, was very surprised at how much I was around. I was a big pain. However, I’d always conceived of Vermithrax as being the center of the drama. In other words, he was my star. And insofar as I was able to do it, I wanted to be able to walk out on his set, pull his big head down and whisper in his ear: ‘Don’t look so far right. Don’t be so close to the boy. Remember, you’re not angry; you’re very cold.’ Or: ‘Now you’re angry.’ In other words, I was directing, from my point of view, the lead actor. So apart from the fact that I was around here to make sure that things came out as close as they could come out — just in terms of speed of action and lining up the shots and that sort of thing — I wanted to be in contact with what the animators were doing with the figures, so that they would seem to have the appropriate gestures. Puppet animation includes the concept of acting.”

Hal Barwood recalled a specific shot in which Robbins modified Vermithrax’s performance. “Phil had programmed the dragon to come through the cave after the babies are discovered to be dead. And he had him coming through the cave with his head kind of turning from side to side. I think what Phil had in mind was that that was a natural part of its gait, but the effect on screen was that it was paying no attention — like it was just kind of out for a romp in the cave — when really what’s going on in its tiny little dragon mind is: ‘I’m gonna get the sucker who killed my babies!’ It needed to have its face coming right toward you, full of menace. Well, Matthew got a chance to see that played back on video and say: ‘Wait a minute. Let’s change that.’ And Phil did. But the rest of the move was still there in the computer memory and could be retained and put into the shot.”

While reshoots were possible, they were not free. Robbins still had to weigh time and budget against dramatic impact. “There were occasions when I felt something absolutely crucial had to be achieved, and it would take them an extra two or three days, and much worry, to get something the way I wanted it. An example of that is the shot where the boy is down in the lower left in the cave, looking back as the dragon appears, having just shot flame at him. The boy turns and runs out, and

the dragon follows. Well, in the original setup, the dragon was going to take one step after him. Then we'd cut, and we'd see there's a chase going on. But I really felt the need to have the boy run out and that dragon, in the same shot, take *several* steps to go after him. Now, to movie audiences, questions like this are absolutely crazy. But once you're into that world of tying the people with the creature, something like that is the announcement of a whole beat in the story; and I thought that it was very important that we squeeze as much out of the shot as we could. So Phil took an extra two or three days with it. He moved the camera a little bit, and we moved the VistaVision plate a little bit, and he had tremendous problems concealing the rods. But once he licked it, the shot was just unbelievable the way that thing comes right after him. So that's just one of those cases where enduring the doubt that we *all* had turned out to be worth it."



Effects cameraman Rick Fichter takes a light reading as Chris Walas prepares to operate the articulated half-scale closeup dragon.



Phil Tippett attaches wings to one of the flying dragons used in the effects photography.



Animator Ken Ralston was largely responsible for producing the flying dragon shots.

Something that distinguishes *Dragonslayer* from many effects films is its overall seamless consistency, despite a wide variety of locations, composites, scales and techniques. Clearly, all involved were united in an effort to make the effects seem part of the film's naturalistic, if fantasy-charged, environment.

Dennis Muren tackled the sticky problem of putting an animation puppet into a smoky cave. "When we heard they were going to shoot in smoke, we just said: 'No, let's don't even try it. It's too hard.' But then that would have compromised the look of the whole film. Derek Vanlint had shot *Alien*, and that was all shot in smoke. That was his style, and Matthew and Hal liked the idea. So, instead of trying to talk them out of it, or trying to make the cave sequences and flying sequences different from the rest of the film, we decided to go ahead and try it.

Often it's not done that way. Often, you compromise the entire film for the effects sequences. We figured, with our resources here, we could come up with some way to make that stuff look like smoke."

In the case of the full miniature sets, this meant using selectively-lit scrims — sheets of filmy material placed in the sets (something like windows extending beyond the edges of the shot) to give a feeling of increased aerial density. One placed between the dragon and the cave set piece behind it, for example, would make it appear as though there was a light haze behind the dragon. Uneven lighting on the scrim could make the smokelike haze look thicker in some places than in others.

However, when the decision was made to go with bluescreen, a different approach had to be found, and the problem landed with Bruce Nicholson and the optical department. After considerable experimentation, they devised a system of selective flashing and diffusion of individual composite elements. Flashing entails exposing undeveloped negative to a low level of white light. This softens and desaturates any image then put on that negative, giving the image a slightly washed-out look. Diffusion has a similar but subtler effect and is achieved simply by placing various semitransparent materials, such as nylon, in the printer's optical path during certain compositing steps. Both effects are similar to the effect that smoke has on original photography. "That's all smoke is," Muren pointed out, "just illuminated atmosphere. The only thing is that our smoke isn't drifting. But most of the live-action stuff isn't drifting either. They'd smoke the whole stage up and then wait for it to be real still. So all of our stuff— all of the bluescreen and most of the other stuff — was either done with scrims or with selective flashing of the elements. The dragon would have a certain layer of flash on it; and then the background would have more flash than that to look like there's more in the air. The flash elements would actually be shot separately with an illuminated source, brighter on one side, darker on the other — so it's not an even, overall flash. Bruce had to go through a lot of trial and error to come up with ways to do it — to keep the grain down and match the colors."



As time drew short, he was assisted by Tom St. Amand, who had earlier designed and built the dragon armatures. For shots requiring the dragon to fly directly over the camera, the puppet was filmed upside down and in reverse so the rigging would not interfere with the shot. A video animation camera, aligned with the VistaVision film camera, enabled the animators to preview their shots and make adjustments as needed.

More than just grain, color and density had to be considered in matching the miniature and full-scale sets. “The drawings that I did,” Dave Carson recalled, “were much more designed and much more moody. But Dennis is really good at matching miniature stuff to full-sized, and he just kept saying, ‘Something isn’t the same here.’ So we’d go back and look at the live-action again. I saw that reel a lot of times.” The difference, Muren determined, was largely in the way the full-scale sets had been shot during the rush of live-action shooting. There simply wasn’t time to make each shot feature an immense cavern with tunnels receding into misty distances. “So we built a couple of cave sets and stuck a camera in there and just shot part of it exactly like they would have done if they had this twenty-ton mechanical dragon on the set and they had to get a shot by the lab run.”

In a brief sequence in the cave battle, virtually everything but the flying dragon is intercut many times. Actor MacNicol leaps onto the full-scale head and stabs it — his lance emitting animated flashes as it enters. Chris Walas’ closeup dragon reacts in pain. The walking dragon tries to buck the four-inch Galen puppet off. MacNicol flies off the full-scale head. The closeup head slams into the roof, smashing a stalactite. Galen stabs the full-scale head from below, lodging his lance in the neck. The closeup dragon writhes in pain. The full-scale dragon writhes in pain, yanking MacNicol around on the end of the lance. In a staggering wide shot, the walker does the same with miniature Galen. The lance shaft breaks; MacNicol is thrown to the ground. The walker digs desperately at the lance in its neck (dispelling totally any concern that Tippett might be unable to extract an emotion from the dragon mover). Finally the full-scale claw comes down on Galen’s shield and he must pull it free. Miniature and full-scale sets and dragons, animation, traveling matte, original photography — all blended with a level of perfection that has rarely been equalled.

In years past, such a sequence would probably have been hurt most by obvious traveling matte work. Bruce Nicholson advanced some ideas on what places ILM’s work so far ahead of most competitors. “There’s been a lot of innovation in bluescreen in the past five years, and we’ve kind of evolved with it. We have a great bunch of people who communicate well and put their minds to solving certain particular problems which get into very subtle areas. Also, we have the advantage of working on features, as opposed to working on small inserts for things — so we have an extended period of time to work. We can talk to the director, and see the dailies, and have time to work things out, whereas a lot of times a normal optical house doesn’t. They’ve got to have the results immediately, so they’ve got to find the quick-and-easy solution. Also, all our intermediate steps are done in-house. It’s a complicated process, and a delicate process. You have to control each step, and this allows us to do that. We process all our material here, so we can test and retest and see our results right away instead of sending it to a lab and waiting a day.”

Relatively well-known by now, at least in special effects circles, is ILM's preference for the back-lit fluorescent blue screen. The alternative approach is to light a blue-painted cyclorama from the front with banks of arc lights, but this does not generate as pure a blue light as the fluorescent-lit screen. "It's more blue-efficient, so we can get an exposure on the negative that is less contaminated by red and green. This makes it easier for us to work with. Also, as far as spill light is concerned, it's generally better, compared with front-lit bluescreen. On *Empire*, all the cockpit material was shot front-lit bluescreen, and we did have some spill problems with it. It was exposed very well, as far as that goes, but there were a lot of reflective surfaces and a lot of spill."

Normally, live-action photography requires a blue screen so large that a fluorescent one would be prohibitively expensive to build. However, Barwood and Robbins wanted the highest quality traveling matte they could get. "We found out," explained Barwood, "by the care we took in storyboarding, that we would not need a huge blue screen. We were pretty sure we'd get away with it if we had one thirty-two feet wide, so we built a fluorescent blue screen thirty-two feet by twenty feet. It's an exquisite piece of machinery." (It has since been purchased by Lucasfilm for use on *Revenge of the Jedi*.)

The custom blue screen was needed primarily for the final battle sequence. "They decided to shoot all the actors bluescreen," Dennis Muren explained, "because they hadn't decided at that time what the background was going to be. Any time that comes up, it's a good idea to shoot bluescreen for continuity, so that in six months or whatever — once you come up with the look of the film — you can add something to it and still be in continuity." Such a decision, however, puts an extra burden on the effects facility — a burden which, on *Dragonslayer*, was felt particularly by editorial coordinator Art Repola whose job it was to keep track of all the many film elements. "It was a very complex sequence," Muren continued. "Not many films end with ten minutes of bluescreen actors in front of created backgrounds."

The created background eventually decided upon for the final battle was to be exotic skies of boiling clouds. Time lapse background plates of cloud formations were filmed by Rick Fichter in Hawaii, using polarizing filters. Then the optical department further filtered and altered and balanced the images to make the clouds seem more like they were lit with "eclipse" light. The shot of the swirling



Shots of the strafing run over the Urlander village were a combination of Ken Ralston's motion control dragon photography, cel-animated shafts of flame by Garry Waller, and live-action pyrotechnic effects on the background plate.

image

Most of the backgrounds featured in the final confrontation sequence were matte paintings produced by Mike Pangrazio and Chris Evans under the supervision of Alan Maley.



Lightning bolts called forth by Ulrich were generated via cel animation by Garry Waller and John Van Vliet.

clouds slowly coming to a standstill was created using a very lengthy shot of clouds filmed at normal speed. The effect of decelerating time lapse was created by making a skip print of the footage. One frame was printed, then many frames skipped, then another frame, and so on, skipping fewer and fewer frames each time until finally no frames were being skipped and the image was again a normal twenty-four frame-per-second shot of clouds.

The very first cloud shot, where one enormous cloud fans out from beyond the horizon, was a different matter. It had been thought that time lapse could create the desired effect, but it was found that clouds simply do not do this. “They were real insistent,” said Muren, “that they wanted the sky to be clean and this one billowy cloud to come up. We didn’t want water tank clouds because those were being used on *Raiders* and we wanted the two shows to look different. So we ended up doing it with the same smoke concoction we used for all our smoke stuff— the crashing dragon and everything. It was patterned after the smoke in the meteors in *This Island Earth*. I showed a videotape of it to the guys and said: ‘That stuff’s terrific. Can you do that?’ And Thaine Morris, our smoke man, said, ‘Yeah I know what that is.’ So we had this really great dense-looking smoke. That was under a sheet of mylar, transparent, lit from the top. The smoke rose and hit the transparent mylar and just sort of fanned out. We were never able to quite get rid of the reflection, but it sort of worked out.”

For all its advantages, the decision to shoot the climax blue-screen did present Nicholson’s department with the special difficulty of making mattes which would not break up or fringe on the wispy edges of Peter MacNicol’s curly blond hair. Nicholson’s staff struggled with this one for a month. “We tried hi-con stock; we tried 5302 black-and-white release print stock; we tried separation stock. We also tried different types of developers. As it worked out, we ended up using a combination of two different stocks to get the matting process to work. We found that as far as the hair was concerned, the 5235 stock conformed better to the original separation than anything else — probably because the original separation is on 5235 also. So we ended up using that for part of our process. With the hair problems that we had, I think the fluorescent blue screen helped us immensely because there wasn’t much spill. We did have some fringing problems, but we were able to control them because the amount of blue light we were getting from that screen was substantial enough that it gave us some flexibility. A matte’s size, and therefore the quality of its fit, can be varied slightly with changes in exposure. So you don’t want to get into a situation where you’re trapped into one exposure, because if there is a problem, it leaves you with nowhere to go.”

Many times, of course, special mattes had to be drawn by hand, frame by frame — a tasking that fell to ILM’s animation department, supervised by Sam Comstock. It is these animators’ meticulous, invisible work that makes the flame appear to come from directly within the dragon’s mouth, and also removes the dragon mover rods when they could not be blue-masked in the bluescreen setups. In addition, when the light from the blue screen did occasionally reflect off the dragon, causing a hole in the resultant black-center (cover) matte, it was Comstock’s crew who repaired the hole. “The fact that it was a sort of slimy rubber creature was the main cause of the problem,” said Comstock, “and it wasn’t very bad on most shots — just a few very tight shots. In the easy sort of blue spill problem, it’s a blue area well within the model, away from the edges. In that case we just make a shape that will block it out, so that optical can use it in conjunction with their black center for the dragon. But the ones that come toward the edges have to be done more carefully — articulated.

Even then, we try to shy away from the edge a bit, just to make sure the artwork look doesn't interfere with the true edge very much."

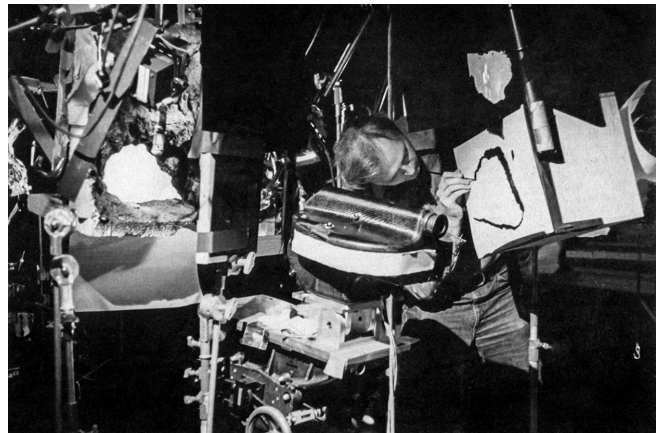
Like many of the ILM staff, Comstock seems an incurable perfectionist. He was mildly dissatisfied with some of the closeups of the dragon breathing fire. "There was a little trouble on some of them with teeth. What looks like a matte line isn't really. It's the shadow of the part of the tooth that wasn't illuminated, and that's just the way it had to be lit. It doesn't really light up the way a bunch of flame inside his mouth would light it up. So there wasn't a whole lot we could do about that. If you have a tooth that's lit from one side, it's going to be dark on one side. It would be too fastidious — even for us, I think — to try to animate in illumination for each tooth."

The animation department also prepared about a hundred and twenty shots they call "animatics." "Pretty early on *Dragonslayer*, we started animating the effects storyboard in rough fashion — pencil animation — to help the director visualize what the final effect was going to be like, and to find out if the board was really representing what was going to work. That way they have a piece of film they can cut into the live-action to see if the timing and movement are correct. It's my contention that it definitely saved quite a bit of time and effort out on the stage, by determining in advance how long a shot should be, how much movement and what direction the movement should go — that sort of content. The movement of the dragon was something that we were very concerned about in advance. We tried on a number of the dragon shots to animate it very exquisitely to show the sort of thing that it would have to do. Thinking back now, our animatics, in many cases, turned out different from the shots; but they helped make decisions on why a shot should or should not look that way. Some of them came out very close."

Though previous animatics, for *The Empire Strikes Back*, were shot in a very rudimentary way — using a small Eyemo camera on a stand — the animatics for *Dragonslayer* were shot using ILM's VistaVision Oxberry animation camera, taking advantage of the pan and zoom controls it offers to enhance the movement while cutting down on the number of drawings needed (to fly the dragon across frame, for example).



When the dragon blasts Ulrich from the air, live-action photography of Ralph Richardson was superimposed with a stream of fire, and then Ken Ralston carefully matched his hovering dragon to the source of the flame.



For the tilt-up shot from the dragon to Galen in the cave sequence, live-action footage of Peter MacNicol was projected onto a white card incorporated into the miniature setting. Since smoke was to be reflected into the scene with a beam-splitter, Dennis Muren painted a holdout matte corresponding in shape to the cave opening.

Not all the department's work was invisible, however. Garry Waller animated the magical shooting stars, as well as the flame which shoots from the flying dragon during its strafing attack on the Urlander village. Waller and John Van Vliet did the lightning bolts seen during the final battle. For the climax, Loring Doyle created the extra-bright amulet glow, matched to follow the amulet when Galen picks it up just before smashing it. Portions of the eclipse of the sun were also handled by the animation department. "From the point where it becomes a total eclipse, it's entirely an animation shot. The corona effects and things were animated artwork designed by Dietrich Friesen. It's a couple of passes, basically on a moiré pattern, that we then softened with diffusion material and shot through color filters." The pre-total shots included material filmed by effects cameraman Jim Veilleux, and a matte painting by Mike Pangrazio.

Pangrazio and Christopher Evans, working with Alan Maley, created the beautiful matte paintings in the film. All of the background mountains seen during the final battle are painted, as are the before-and-after wide shots of the landslide area at the dragon's lair. The torch-lit castle seen at night, and the daylight long shot of the castle with horsemen riding toward it, are superb paintings which defy detection. (Another almost fully-completed painting, involving the Urlander village, was cut during the drastic editing to shorten the film.)

The castle-horsemen shot features a technique Maley pioneered, the use of front projection to combine live-action with a painting. The painting is on glass, and a clear space is left in it, behind which a front projection screen is mounted. A camera can then photograph the painting and the projected image together — actually, on separate passes. Both castle shots include subtle camera moves, part of Maley's effort to get his shots to blend imperceptibly. "I have a great theory about matte painting, that if you set it up like a matte shot, it'll look like a matte shot. But if you shoot it as you would a production shot, you tend to take the curse off it. The better the shots are, the less you're going to notice them — and I don't think you should notice matte shots in movies. You can do a beautiful matte shot, but if it doesn't cut with the two shots around it, it can ruin the whole thing. So it's very important, especially when you're building sequences, to know exactly how it's going to cut."

With everything that was done at ILM, it was still necessary to contract out some of the optical work. Since ILM's animation department was equipped to handle only large-format VistaVision footage (eight perforations per frame), it proved practical to have the Panavision (four perforation, anamorphic) footage handled elsewhere. Most of these shots were done in Los Angeles at Visual Concept Engineering, an independent effects facility founded by Peter Kuran, an ILM alumnus who had worked in the animation department on *Star Wars* and headed it on *The Empire Strikes Back*.

VCE had six months to create the flames in Ulrich's bowl, the magical heating of Galen's lance for forging, the bright flashes from the clashing weapons of Tyrian and Galen during their fight, and the fiery resurrection of Ulrich. They also did a host of less-apparent shots, numerous amulet glints, and the like. Much of the work is so subtle as to go unnoticed, even after two or three viewings. When Galen enters the camp of the Urlanders to announce that he is their new sorcerer, he causes a puff of smoke to come from their campfire. To the live-action pyrotechnic puff, Kuran added a tiny, almost subliminal, wisp of flame that rises with the smoke.

Like his counterparts at ILM, Kuran strove for a look of naturalness. Interestingly, the effort often led him to create photographic imperfections. For him, it is a perennial battle between artist and technician. “The idea is to make it look like it should be there. In a lot of cases, I think people that are very technically involved don’t think beyond the technical aspect. For something to look real doesn’t necessarily mean it has to look technically correct. The technician wants it correct, and the artist wants to do it from ... God knows what — it just flings in from the top of his head and lands on the paper. Somewhere in between those two, I think, is what it’s actually supposed to look like.”

In his struggle to achieve that middle ground, Kuran has put himself in a position of considerable creative control. Particularly, he shuns the potentially bureaucratic muddle of individual departments, which can characterize a large effects facility, by personally overseeing each phase of his operation. Once the artwork is generated and photographed, he follows the film next door, where he maintains an easygoing relationship with the printer operators at RGB Optical Effects. There he watched over the compositing of each shot VCE did for *Dragonslayer*. His painstaking effort helped to ensure that the four-perf effects footage would intercut acceptably with the VistaVision effects footage — which has the edge in image quality — as well as with original photography.

Kuran is an assiduous observer, not only of what things look like, but of what they look like when photographed. He advised animator Susan Turner to study candle flames until her pencil tests took on the degree of randomness-interrupted-by-pattern that flame actually possesses. Hers are the flames in Ulrich’s bowl. They even have a faint inverted reflection of themselves flickering beneath the main image, because that’s what a normal camera lens would have photographed had the flames actually been in the bowl during stage photography.

Matthew Robbins was particularly interested in realistic lens flares, and VCE provided them. In the swordfight between Tyrian and Galen, if the weapons had actually given off flashes of light during photography, the Panavision lens would have exhibited its characteristic pattern of internal reflections and horizontal bars of light. It was not possible to get the proper look with a high-quality animation camera lens, so Kuran looked elsewhere. “You have to have the ability to close the door and just sort of Rube Goldberg-it together and make it work. An Oxberry is a sixty- or seventy-thousand dollar piece of equipment that should be able to provide you with *everything*. But what it does is it provides you with a lens that can’t flare, because years of technology have come together to create this lens that won’t do that. So if you need lens flares, you take the piece of film, you go out and rent several different lenses, and you find the one that has the most elements and the least problems.” Lens flares for the swordfight sequence were shot with a conventional Panavision lens on a Mitchell camera. These flares were then augmented considerably with additional artwork for the flash at point of contact, the bright blue line extending across the frame, and the effect of the light on the actors’ bodies. Less elaborate flares, like the glints of Galen’s amulet seen throughout the film, were done with artwork alone.



Numerous cel animation effects were added to the anamorphic stage photography by Peter Kuran and his staff at Visual Concept Engineering. The flickering wisps of flame emanating from Ulrich's bowl in the opening of the film were animated by Susan Turner.



The swirling column of flame from which Ulrich is resurrected was attempted live during principal photography, but since only a few frames were usable, these were cycled optically and augmented with animation to conceal the fact. The spinning form of Ulrich within was straight animation, done by Katherine Kean.

One of the most complex sequences done by VCE was Ulrich's resurrection in the *Lake of Fire*. The storyboard called for a whirling column of green fire, but an attempt made on the set to obtain this effect was deemed unsatisfactory. "I would say that out of all the pyrotechnics that were shot in England, there were probably about ten frames that looked like they were usable for something, and they looked really good. The flame that we used incidentally, was pulled out from an image about the size of a 16mm frame; so it should have been pretty grainy, but it wasn't." To get the necessary length for the shot, the short piece of live flame was repeated over and over. Then, a considerable amount of animated flame was added, including small random juts to help conceal the fact that the live flame was being cycled. The green, iridescent spinning form of Ulrich is pure cel animation, done by Katherine Kean.



VCE also added lens flares and animated light flashes to the swordfight sequence between Galen and Tyrian.

For the heating of Galen's lance, considerable thought was given to what molten metal looks like, and artwork was generated to take the lance blade from red hot to white hot. "For each color that came on, there was a different set of artwork. The red starts out, and once it gets fully to the edge of the blade, it stays there for the rest of the shot. Then from the point that the red started — ten or twenty frames into it — a sort of red-orange starts. Since it's continually getting hotter and hotter, it's continually eating away density from the different passes. Finally it gets into a white pass." To help keep the registration of the effect perfect, VCE made artwork for each frame of each pass — even when the blade is down on the anvil and relatively stationary.

From a special effects point of view, *Dragonslayer* will of course be remembered as the film which pioneered go-motion. But the very existence of the process raises at least two questions: Is this technological encroachment good for the art of animation? And what is the future of the process?

The first question gets short shrift from the ILM people. They are of one mind that the technique greatly improves the look of the animation and that the animator sacrifices nothing by using it. "It has to be said over and over again with all these mechanisms," said Stuart Ziff. "If there were not skilled animators, it wouldn't matter how good the mechanism is. That's the bottom line." Tom St. Amand agreed: "It's like a surface gauge in a way. You use a surface gauge to get the movement smoother, and nobody cringes at that idea. It's just a tool. It doesn't actually do the animation. You're using it to make the animation better. And that's what these things do."

As to the question of how this 21st century surface gauge will fare in the future, its developers, naturally, are bullish — perhaps not without reason. First of all, the dragon mover is not just a dragon mover. Ziff's erector set design makes it potentially suitable to tackle most any critter with an average number of appendages.

There hasn't really been time to consider how the system might be improved, though Muren's mind runs to simpler, more exotic programming techniques. One possibility is the use of some sort of wand tied to the computer in such a way that the computer can sense its position in space. Any

movement of the wand would be automatically duplicated by the puppet. To program, the animator would simply sit and wave the wand.

On the negative side, the system's reliance on traveling matte to hide the rods has drawbacks. It means that the kind of precise, apparent physical interaction between live-action character and puppet, routinely done by Ray Harryhausen through his rear projection techniques, could be considered more difficult.

Finally, there is the question of production time. Including programming, shots with the dragon mover took longer than the same shots would using conventional animation. Would the technique be practical for, say, a *Clash of the Titans*-type film calling for much more animation footage? "I don't know about that much volume," cautioned Muren, "but we can do it a lot faster than we did on *Dragonslayer*. The two-week shots we had were ones where either Matthew was trying to get a specific feeling, or Phil was trying to learn how to use the system. Now he's got that all worked out. I think it could be done with volumes, but you would do it with three or four go-mo units shooting over a period of six months — not just one over a period of two years. It'll never be as fast as stop-motion."

Even so, go-motion's boosters raise an interesting question of their own: Is good old stop-motion good enough for today's audiences? "We got a lot of negative feedback on the tauntaun," Muren remarked, "which first got us thinking in this direction. We thought the tauntaun was really neat — you know: bright daylight, running along and everything. But you ask the average guy, and he thinks it looks fake. At that point we figured, 'There's something wrong here.' All of us have similar feelings about things; that's why we're friends. But that also means we have something going on in our heads that forgives things that other people won't forgive. I think that 'forgiving' audience is the same audience that goes to the Harryhausen films; and that market is, say, maybe \$20 million. But now these films cost \$18 million to make — and you need to get forty or fifty or eighty million back on them. So you've got to get those other people, too."

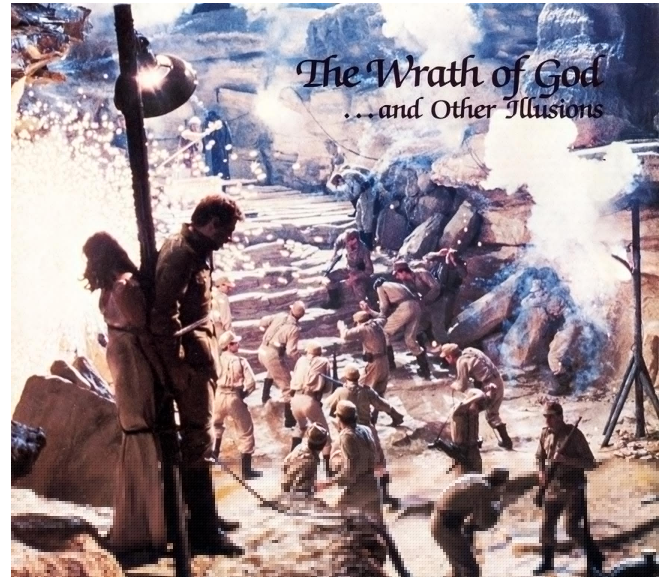
If that is true, go-motion may just be the way.

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Steven S. Wilson is an animator and writer living in Southern California. As a USC graduate film student, he won more than a dozen international awards for a 1975 short subject, *Recorded Live*, and has since done dimensional animation and other effects for a popular series of educational films. His recent book, *Puppets and People*, is the definitive work on stop-motion special effects techniques. In addition to his technical writing, Wilson has produced comedy material for Warner Bros. Cartoons and Chuck Jones Enterprises.

The Wrath Of God ...and other ilusions

article by
Don Shay



The announcement was a studio accountant's dream come true. Longtime friends George Lucas and Steven Spielberg, collectively responsible for four of the top ten money-making films of all time, were joining forces to produce *Raiders of the Lost Ark*, an unabashed throwback to the episodic cliffhangers of Hollywood's B-picture heyday. With \$20 million of Paramount's money and a projected 85-day shoot, Lucas and Spielberg chased across three continents to bring their escapist fare in on budget — twenty days under schedule and miles ahead of all but one of the heavyweight contenders for the 1981 summer boxoffice sweepstakes. But at the time principal photography wrapped in September 1980, the monumental climax to the tale was still largely in the minds of its creators. Its transmission onto film lay yet ahead for the staff of Lucasfilm's in-house effects facility, Industrial Light and Magic.

Set in 1936, the plot to *Raiders of the Lost Ark* centered around a resurgence of interest in the long-lost Ark of the Covenant, a sacred gold-encrusted chest said to house the shattered fragments of the original *Ten Commandments*. Unseen since its disappearance from the Temple of Solomon nearly three thousand years ago, the Ark — as prophesied in the Old Testament — was to be recovered at the time of the coming of the true Messiah. In a bid to secure the priceless artifact and thereby legitimize his lust for world dominion, Adolph Hitler launches a massive archaeological quest into the Egyptian desert. When U.S. Army Intelligence reports begin to suggest that deliverance of the Ark into the hands of the Nazis may indeed be imminent, government agents recruit Indiana Jones, a maverick archaeologist and soldier of fortune, to find it first and thwart the Fuehrer's plans. After numerous adventures and more than an occasional setback, Jones uncovers the Ark, only to have it wrested from him by his archrival Belloq and the Nazi forces. However, when Hitler's emissaries open the vessel to verify its contents, they are rewarded not with power and riches, but with unspeakable devastation and death.

"When you do a space picture," reflected ILM's visual effects supervisor Richard Edlund, "you're dealing with a fantasy which takes place somewhere nobody's even been, so you can get away with all kinds of stylistic things to make the film look good. With *Raiders*, we were in a fantasy situation also, but one we could take fewer liberties with since it was set in a more recognizable locale and

time. In fact, *Raiders*, I guess you could say, was kind of a direct descendent of films like *The Mummy* and God knows how many others that were generated from actual newspaper headlines dating back to the period when Tut's tomb was discovered and there was a lot of archaeological stuff going on. So here we were in 1936, faced with the problem of maintaining some semblance of realism and yet at the same time coming up with a style and a look for what I guess you'd have to call the wrath of God."

Effects art director Joe Johnston, veteran of both *Star Wars* films, was one of the earliest ILM staff members to become involved in the project. "I was asked by George and Steven to come up with some kind of an effect — or at that time, it was really a series of ideas — for the ending of *Raiders*. George kind of outlined what he thought it should involve, but at that point the script was pretty vague. I think it said something like: 'The Nazis open the Ark and there's a giant holocaust' Not a lot to go on, but that's the way George works. He likes to give somebody an idea and then see what he'll come up with." Johnston set about putting his thoughts on the subject into a series of storyboards — conceptual blueprints preliminary to most effects work, but which on *Raiders* were employed as well throughout the complex main unit photography. "In the beginning, I planned to have a lot of strange things happening, but I really felt that fire should be the strongest element and so I came up with this cataclysmic kind of pyrotechnic effect with melting Nazis and the whole island going up in a giant firestorm that could be seen for a thousand miles around."

While Johnston developed his concept, revising and refining portions after consultation with Lucas and Spielberg, two other artists — Ed Verreaux and Michael Lloyd — were similarly engaged, working independently out of Spielberg's Los Angeles-based headquarters on the M-G-M lot. "It was interesting," Johnston continued, "because we all approached the sequence from different points of view. One of the treatments was real subdued. Everything would be kept quite dark and there would be these strange light effects — like rays — that would come out of the Ark and pierce people. Then, once they'd been pierced, the Nazis would just disintegrate and turn into powder. The other one dealt mostly with ghosts. After about six weeks of this, we took all of these storyboards — probably about a hundred and fifty of them — and sorted them out on a table; and finally I was given the job of combining all three into a single sequence. What I did was I'd take a few of my boards and then when an idea kind of trailed off, I'd stick in somebody else's — the whole idea being to use the best of each and come up with a cohesive sequence combining as many of the different effects as possible."

"George and Steven set out to make *Raiders* kind of a tongue-in-cheek B-picture," said Edlund, "and that attitude carried over into the shooting as well. In fact, the picture was directed at an enormous breakneck pace that put me in the unenviable position of having to follow the act of Steven Spielberg at his virtuoso best. Almost before we knew, principal photography was over, everybody was back from England, and we were left with the end of the picture."

Only three days had been allotted for main unit shooting of the crucial Ark sequence. The altar setting, situated in a rock-hewn natural enclosure reminiscent of the Devil's Tower landing site in *Close Encounters of the Third Kind*, was fabricated on a sound-stage at EMI Elstree. Richard Edlund flew over to supervise the shooting, much of which would later be enhanced with matte paintings and optical effects. Three days proved adequate to obtain the long shots required for the sequence, but most of the time-consuming closeups and effects shots were set aside to be done later. The Ark and

other key set pieces were loaded into a large cargo container and shipped to San Rafael where a forty-foot-long replica of the altar setting was being duplicated in a warehouse across the street from ILM. “Originally,” said Joe Johnston, “they planned to do the whole thing in England. But we realized once we had the sequence boarded that a good portion of it involved closeups of maybe one or two guys and that a lot of those shots were going to require a great many takes to get it right. So it proved out to be cheaper and easier to do it over here. We had the space. It wasn’t huge, but it was big enough to shoot three or four people at a time — your basic four-Nazi stage.” Once the setting was substantially reconstructed, Richard Edlund carefully matched the lighting to Spielberg’s completed stage photography and commenced shooting a variety of pickups and inserts, as well as the background plates required for most of the effects work. Meanwhile, the remainder of the ILM effects unit assigned to *Raiders* was already heavily involved in devising and testing techniques to achieve the desired illusions.

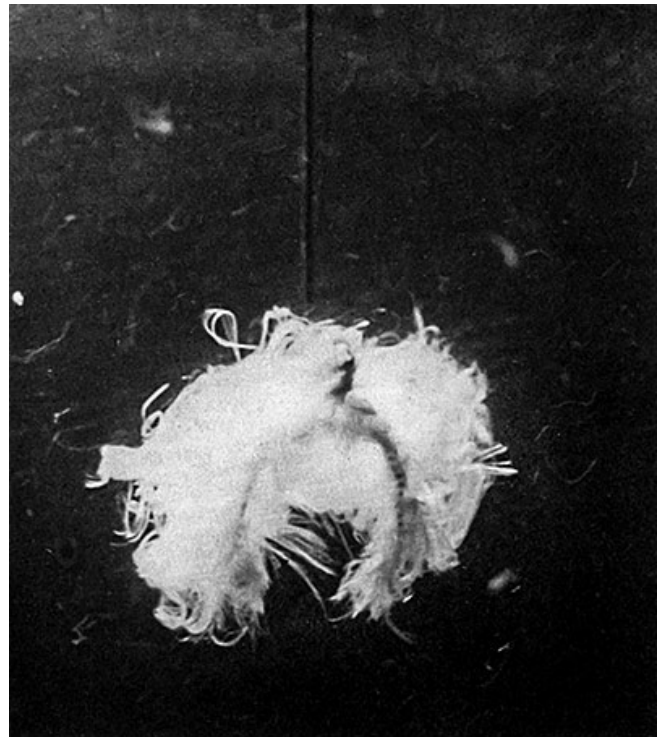
An immense amount of effort went into creating the ghostly apparitions which issue forth from the Ark once it is opened. “The problem with presenting ghosts,” said Edlund, “is that people seem to have a hazy fantasy of what they think ghosts should look like; and if you disturb that too much, or if you present something that doesn’t come up to snuff, then people are going to reject it.”

The original approach was to have placed an enormous burden on the animation department, which in addition to *Raiders* was also serving the *Dragonslayer* unit. In anticipation of the added workload, Dietrich Friesen, formerly of Graphic Films and the Robert Abel organization, was hired on to assist ILM’s resident animation supervisor, Sam Comstock. “I suppose it seemed logical that the ghosts be animated,” said Comstock, “but I frankly had my doubts that we could ever turn out that much work with all these complex ghosts swooping around. But we said we’d give it a try, and so we went through a lot of testing and development. At the same time, though, everybody all over the building was experimenting with different ways of doing it, and as a result, most of the ghost footage wound up being done in a water tank.”

The water tank ghosts were fabricated by model-maker Steve Gawley from bits of silk fabric fitted over wire armatures. Gawley also manipulated the ethereal manifestations, drawing them through the water by means of hidden wires which ran to a



Once opened by the Nazis, the long-lost Ark of the Covenant begins to spew forth a plethora of ghost-like apparitions.



Although some of the ghost images were produced via cel animation, most of them were derived from underwater

platform positioned above the giant aquarium-like tank. “One of our big claims to fame at ILM is motion control photography,” Richard Edlund remarked, “where you have *absolute* control over everything and you can position things exactly the way you want them, and then program it that way and shoot

it. But in this scene, we were dealing with a phenomenon where it was not possible to do that. Everything had to be done by hand, and the ghosts required a lot of choreography and rehearsal. First we built a camera with a device in it for putting a clip from the live-action in the finder so we could actually look right through the scene and get our positions and relationships that way. Then I’d look through the clip and kind of talk Steve through the motions. He’d practice until he got it right, and then we’d do a number of takes that we could project up on a screen, superimposed over the live-action scene, so we could pick the ones that looked best. It was pretty tricky to match because we had to have them flying around some of the guys in the scenes, and yet not eclipse themselves, which would have made it impossible to matte. We did thirty or forty takes on some of those shots.”

On the surface, a simple double-exposure would seem to be an adequate means of compositing the ghost imagery with the live-action background footage, but this approach was ruled out because to do so would mean that the ghosts would get lighter and darker as they passed in front of light and dark areas on the plate — in essence, betraying the technique and diluting the effect. “The ghosts were supposed to be kind of semitransparent,” explained optical supervisor Bruce Nicholson. “You didn’t want to see through them *completely*, but you wanted to see through them a little bit so they would appear like an apparition. So we made black-and-white cover mattes, and also some very thin holdouts, and we just matted them in. The *real* job was trying to maintain contrast and keep from picking up grain. Basically, with each ghost we rephotographed in, the overall base density of the negative would pick up. In other words, the film emulsion was getting an overall exposure and therefore the contrast would start to decrease. Fortunately, Richard was able to expose his shots in such a way — underexposing them slightly — so that we could reproduce the ghosts acceptably and still have enough contrast to get our mattes.”

In addition to underexposure, Edlund also employed multiple in-camera passes to keep the number of image-degrading optical steps to a minimum. “In one scene,” he explained, “George and Steven wanted this giant vortex of ghosts swarming around in the background. We shot about fifty passes in the camera, and then optical used two supers of that with a matte and a lot of out-of-focus printing techniques, so we ended up with about a hundred ghosts all together.”

“It was amazing how they choreographed some of that stuff,” Nicholson marveled. “Here were all these ghosts going off into little areas behind rocks and behind characters, and I mean it was just incredible that they were able to do it at all. The fact that they were able to give us a negative with twenty-five or more ghost elements on it certainly simplified it for us. To do a hundred ghosts one element at a time, we’d be compositing forever. This way, we were able to use a single set of mattes. There were still difficulties though, particularly in those areas where we had white ghosts matted on top of other white ghosts. It was hard to keep from burning out those areas in the frame, and we wanted to be able to identify all these different levels of ghosts flying around. So we spent a lot of

photography of shredded pieces of silk fabric attached to wire armatures and also manipulated them through ILM’s giant water tank. Effects supervisor Richard Edlund photographed as many as fifty in-camera passes for some of the ghost scenes.

time working out the proper density for our mattes, and often we'd find that we'd have to run the background ghosts with a certain set of densities and then use another set of densities when we were putting the foreground layer in the top. And that became fairly difficult because there were so many ghosts in some of those shots. Of course, there were a lot of roto mattes involved, too. When we got the stage photography from Richard, we'd do what we call a precomposite on the shot — just supering the ghosts in — and then that would go to animation so they would know exactly what frames they'd have to rotoscope to make us a matte of whatever the foreground subjects were so that when we ran the shot all together the ghost would appear to go behind."

Sam Comstock and his animation staff differentiate between the two basic rotoscoping techniques employed at ILM. "The largest number of roto mattes we do are what we call garbage mattes, and they're used simply to fix up a bluescreen element so that all the surrounding light stands and stage rigging don't show up. We have a special garbage matte rig with a projector down below and a camera up above so that we can project a blue-screen element onto a rear screen at the table surface, arrange the opaque garbage matte papers to conceal anything we don't want in the shot, and then photograph the garbage matte as we go along. It's a fairly fast process. When precision artwork is required, however, we call them articulate mattes, and they're done on another piece of equipment — the Barnettomatic — which is a locked-down camera that will shoot at our standard twenty-two-inch field with lock-down pegs. Using that, we can rotoscope a shot to make basic drawings, go back to our desk, work on them for a few days, and then come back and be able to count on it still being aligned." Articulate mattes were used extensively in the ghost sequence. In fact, whenever one of the apparitions had to pass behind a character or object in the shot, all or part of the character or object had to be meticulously hand-traced by one of the animators so an accurate inked silhouette could be rendered, photographed as a matte element, and run through optical with the other portions of the shot to prevent the background ghost imagery from being exposed over that particular area of the frame.

Although the decision had been made to rely heavily on the tank ghosts, some totally animated



Supervising stage technician Ted Moehnke, pyrotechnician Thaine Morris, effects art director Joe Johnston, and Elizabeth Morris adjust the platform harness suspending actress Greta Hicks. Wearing harsh white makeup to suggest a ghostly quality, Hicks was photographed by Richard Edlund in such a way that she appeared to be floating against black.



apparitions did manage to work their way into the film. “They wanted ghosts to wrap around people on a couple of shots,” said Comstock, “and the way the water tank ghosts were being done that would have been extremely difficult. So they asked us to

animate those three or four cuts and make them look as much like the other effects as we could. John Van Vliet did the animation using pencil on white paper, and the actual camera negative was what optical used to pull their mattes and print from. That was for extra clarity, because we shot it soft-focus in specific ways and it was very hard to keep the quality of the soft edges if they were later duplicated — they’d tend to disappear. A lot of it still did. If you saw the camera original of that you’d see a lot more wispy edges and things — but it helped. For the most part, John did his own matting as he was doing the drawings, but we still had to go in with little corrections and articulate mattes afterwards; because by throwing things out of focus and filtering them, it would soften *everything* up, and when it went behind a person you’d want that to be a pretty sharp edge. So we did articulate mattes on separate elements later on to block out part of the ghost.

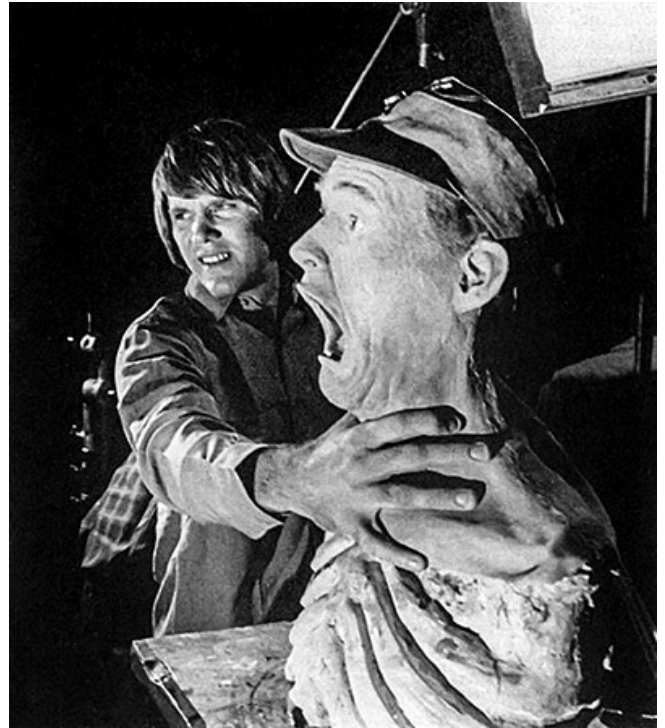
“I think the best and most memorable animation shot — to me, anyway — is the one where one of the Nazis is crouching and slapping at himself with this wispy stuff circling about and wrapping around his body. At the same time, there’s a tank ghost coming out of the Ark in the background and a lot of other things going on. Optical spent a lot of time getting all the color balances the same and making everything blend together. One shot was going to have three animated ghosts in it, but they dropped it back down to two. It was a shot of the Ark and the three characters standing behind it. One of the ghosts was supposed to come up out of the Ark, grab the Nazi colonel by the chest, and then trail off into the air. There was going to be another ghost over on the left that just came up and sort of hovered, and then a third ghost that flew behind all three people. That’s the one they changed to a tank ghost in the final cut — mainly because they thought that having one shot where all the ghosts were animated would make it more noticeable, because there *were* differences. If you stop to scrutinize the ghosts, you can see that our animated ones don’t have the same kinds of trailing tendrils and fibers and things that the water tank ghosts had. So that turned out to be a pretty complex shot. There was the stage plate that they shot, an articulate matte to permit our animated effect to come out of the Ark, the animated effect itself which would be camera original, a matte for that effect which optical pulled off the black-and-white, the water tank ghost, a matte pulled from the water tank ghost, and an articulate matte to permit that ghost to fly behind the three people.”

Not all of the animated ghosts involved painstaking frame-by-frame artwork. “We did about four cuts with a distorted mirror-type effect,” Comstock added, “mostly at the beginning of the sequence — the first few things that come out of the Ark. That was just a simple pattern of dots and shapes that I animated to crawl a bit just to give it some stability. Then I manipulated a projection of that around on a distortion mirror, which bounced the image onto a rear-projection screen where it was rephotographed. Then we did an articulate matte around the top of the box so it would look like these stretching patterns of light were coming out of the Ark.”

The most startling shot in the sequence occurs just before the debacle, when one of the wispy manifestations drifts up toward the camera to reveal a rather angelic-looking female countenance

*This footage was the projected through a night lens's-
haze* sion layer to produce a unique distortion effect which
was enhanced with selective articulate roto mattes and
composited by the optical department.

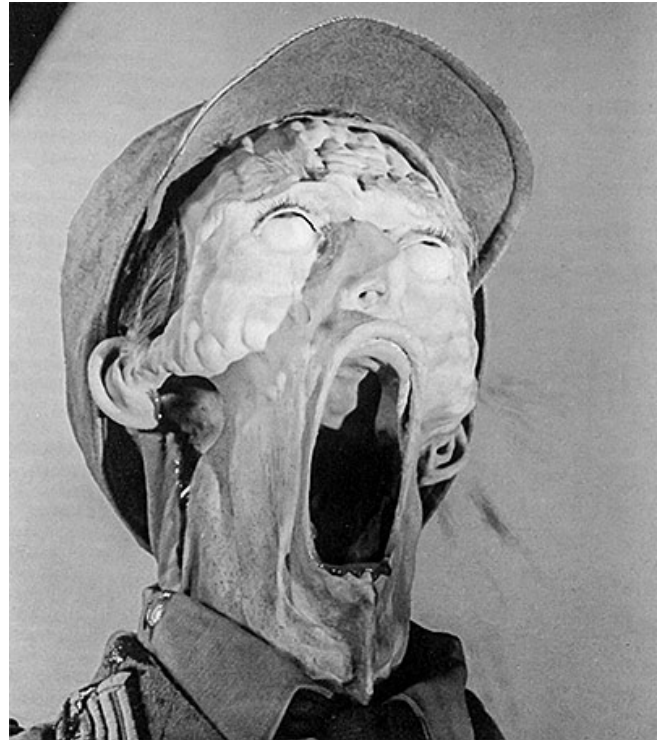
which then suddenly transforms into a ghoulish death's-head. "We wound up with something like a 200-to-1 shooting ratio on that shot," said Richard Edlund. "We brought in a girl and dressed her up in this white flowing gown and had Chris Walas put white makeup on her. Then we put her on a little platform that was hanging by three wires and I lit her with about twenty-five lights — none of which the camera could see — and shot all kinds of footage of her with my old high-speed Mitchell and a zoom lens. Then we went through the material and picked a shot where she lifts her head up and light was changing on her in such a way that it all looked good. Later, I took that camera, put a clip of the shot in the finder, and lined up some identical shots on one of the mummies that had been shipped over to us from England."



Special makeup artist Chris Walas produced a series of three artificial heads for the Ark sequence. The first, representing Colonel Dietrich, employed inflatable bladders which, when pumped up with air, sustained the face's proper shape. Joe Johnston's hand was used in the closeup to impart some added life to the scene.

All the mummies, featured prominently in the escape from the Well of Souls, were produced by the British makeup crew under the supervision of Tom Smith. "They were done using an old technique of covering a skeleton with paper toweling and latex and some detailing," said Chris Walas, who was tasked with modifying the one chosen for the ILM shot. "My job was to dress this particular one up so it looked kind of like the girl. The hair turned out to be the biggest problem — trying to get it the proper consistency so it would blow at basically the same frame rate as the girl's hair had. So I spent a lot of time teasing it and filling it out so it still maintained body, but had that real scraggly kind of look to it. Then someone in the model shop did some rigging on it so the mouth would open up and the head would pull back."

"I lined the mummy up *very* carefully to the clip," Edlund continued, "making sure to keep the hair and the cape and the lighting on the face as close as possible. Then, at the point on the film where the girl was turning her face up, we did a dissolve to the mummy, with the idea being that the movement would help hide the dissolve. At one point I thought about doing some kind of a complex wipe in there, but I later decided we really didn't need it. Then we took that material and had a rear projector projecting it through an inversion layer in our small water tank — one of those salt water/fresh water inversion layer things — onto a rear projection screen. Then we did a pull-back with pan and tilt with our motion control camera head to get the proper movement. That way, everything was under control except for the phenomenon that was going on in the inversion layer, which we'd disturb in various ways to cause distortions in the projected image. It was kind of tricky, because we wanted the layers to mix in such a way that they were disturbing the cloak but leaving the face pretty much untouched, because the distortion we had on the face with no movement at all was already quite adequate. In fact, I wouldn't have minded having a



When the air was sucked out, the bladders deflated and the face became instantly mummified.



Toht's head was made from a multi-layered gelatin compound and was filmed in time lapse as it melted down to the skull.

image

little more detail than I got. We did a number of takes on that and then turned the best of them over to optical.”

“The most difficult thing about that shot was getting the faces to read,” Bruce Nicholson elaborated. “The image had already been duped once before it came to us and there were a lot of shadows on it. So what we had to do was matte it into the shot so you didn’t see through it too much, because if you did, the face would kind of get lost. Animation helped out a lot by making articulate cleanup mattes for us so that the eyes and the mouth and some other areas of the face would be opaque rather than having some print-through. Then we had to get all our densities to match so you’d see through the rest of the figure a little bit, but without it being totally transparent. If you don’t get your densities to match exactly, you’d end up seeing through certain areas more than others and it would have looked ridiculous. Then we also had the fact that this particular ghost was passing in front of some others, so it had to hold those others out so you wouldn’t see them through it. Also, just getting the matte to work well for the outline of the creatures was difficult because it wasn’t shot bluescreen. It was shot against this black water background, but you didn’t really get a black. You’d get more of a dark gray, if you were lucky. So we did our best at pulling mattes from the overall ghost, and if there were gaps in there — and there usually were — animation would go and fill them in for us.”

Once the transformation from angel to demon has been effected, the full fury of the awesome forces within the Ark is unleashed against the Nazi violators. Flames leap forth from the open chest, and in a matter of moments, Dietrich’s face shrinks to a mummy-like visage, Toht’s features melt away from his skull, and Belloq’s head explodes into a pulpy mess. The cumulative ten or twelve seconds of screen time devoted to these phenomena were the end result of many months of intermittent work by makeup effects artist Chris Walas, who was, at the same time, heavily involved with ILM’s concurrent *Dragonslayer* effort.

“Originally,” revealed Walas, “all three heads were planned just to explode, but then I guess once principal photography was finished, they started thinking about what else could be done with the things. We already had molds for the three heads, which were done by Tom Smith and his people in England, but unfortunately they turned out to be pretty valueless except as a basic form. For one thing, they were very large — full busts and halfway down the chest — which is a very difficult size to work with when you’re using anything as delicate as the materials we ended up using. So we had to cut them down and remold them. Also, for some unknown reason, they sculpted the heads instead of taking life molds, which I thought was a pretty

Richard Edlund of the special-effects department had hands before shooting the Frenchman’s face. The final effect employed air cannons, shotguns and explosive charges.

image

Richard Edlund observes as Gary Platek uses a remotely controllable pneumatic arm to produce cloud formations in a huge glass-sided water tank.

image

Various probes, attached to the pneumatic arm, enabled Platek and coworker Don Dow to inject bursts of white paint into an inversion layer between salt and fresh water strata in the tank, thereby creating a variety of atmospheric conditions.

image

One of the more complex composites in the film involved a live-action water plate, a matte painting island, a pyrotechnic pillar of fire (enhanced with articulate roto mattes), and tank-generated clouds.

bizarre move. And they were done just from photos, which meant basically that they were sculpted from one angle and one angle only. If the camera didn't hit that angle, it didn't look like the guys at all — especially since they all had these open-eyed, open-mouthed expressions which you're not really used to seeing them in anyway. So we had two or three strikes against us, just with that."

Assisted by Wesley Seeds and Marc Thorpe, Walas turned his initial energies to the exploding head of the renegade archaeologist Belloq, which would ultimately wind up as the last of the series' three quick cuts. "In *Scanners*," he recalled, "we just simply stuck a shotgun behind a false head mounted on a dummy and shot it off for a very sloppy kind of effect. George didn't want anything quite that gruesome — at least not at first. He wanted it in as many pieces as possible — almost vaporized — so it wouldn't be that gory. The head we ended up using was actually only half a head — the front half — and it was made out of industrial grade gelatin with various different chemicals added to it — pretty much the same as the *Scanners* head. We tried doing the effect first with just air cannons mounted in front of the head; and it started off quite promising, because as the air hit the face, the mouth kind of opened up and started ballooning out — which was real interesting. But once we got past that point, the face would just slide off the skull and that was it. We also tried various kinds of explosives, but we had a problem with those at first because we'd blow the face away and there'd be this jawline sticking out — which was kind of embarrassing. The final configuration was a large air cannon directly in front and below the head, two shotguns placed about fifteen feet or so behind the head and off to the sides — the only safe place to be was directly behind the camera — then we used four or five pieces of primacord to sever the neck and three different dets under the eyes and chin. Thaine Morris handled all that, with the assistance of Ted Moehnke. Inside we had a very thin plaster skull, which we filled with blood bags that had all kinds of garbage in them — dried latex, vermiculite, pieces of foam that were lying around the shop, dragon scales — everything. We shot a bunch of tests, and much to our surprise, George kept saying: 'More blood! More blood!' So we wound up painting the bone red, making the gelatin under the skin red, and just making sure it was all very striking. And it was. We finally ended up shooting about four takes with good heads — the finished heads — and they were tremendously graphic and very bloody. George took one look at them in dailies and said: 'Less blood! Less blood!' "

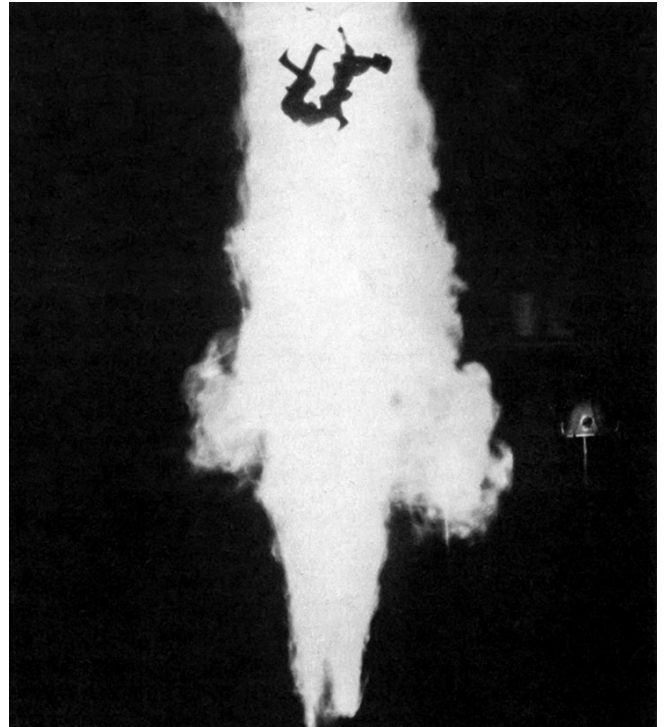
The job of making the effects look less objectionable was turned over the optical department. Since the exploding head was to lead directly into the holocaust shots, it was decided to superimpose pyrotechnic effects to help detract from the gore. "We had to put pyro in front of the head, and also in back of the head," explained Bruce Nicholson. "So we did a dissolve type thing so that when the head explodes, there's actually more pyro being exposed than there is the exploding head itself. It kind of camouflaged it a little bit, without losing the impact of the effect."

The sadistic Toht, whose head was supposed to melt all the way down to the skull in only one hundred frames, presented a significantly greater challenge. "The facial sculpture Tom Smith had done was fine," said Walas, "but frankly, the skull stunk. So that had to be resculpted, remolded, and a plaster positive made. The build-up technique involved first putting a layer of skin-tone gelatin into the negative mold of the face. The rest we brushed directly onto the skull in very thin layers, laying in veins and other things, and checking the thickness by putting it into the negative mold every so often just to make sure the spacing was all fine. We tinted each layer with food coloring or universal color — depending on the intensity of the color and the translucency we wanted to

maintain — so there are about four different colors of red in there. Finally, when we got the proper thickness built up and all the textures we wanted, we put it into the negative mold, blocked it all, and poured in one final thin layer of gelatin to adhere the two. Basically, we wanted the skin layer to be very thin so that the skin color would just sort of drip off and reveal the rest of the gruesomeness. We had already done a couple of rough film tests on the effect, but fortunately we only had to do it for real once, because the build-up process was *extremely* time-consuming. Wesley and I started it at one o'clock in the morning in order to have it ready to shoot at seven the next evening. With the exploding heads, we could make one, bag it up, and leave it for a week. But the melting head had to be done all at once because the gelatin was such a thin mixture that you couldn't leave it sit."

"The melting head was originally planned as a static shot," said Richard Edlund, "but at the last minute I decided we had to get some movement into it or else it would look like a broomstick sitting there. So we put the head on a motorized gearhead so it could twist a bit to the side, and then I plugged the camera into the motion control system and did a pan and tilt on the head just to give it a little bit of movement."

"I'm a firm believer in making the frame as busy as possible," Walas agreed, "especially when you're doing a false person, because everybody knows what a person looks like. With a monster or a creature it's not as important, but with a person it's really critical. So I was glad some movement was added to that shot. It did cause me to forfeit one of the effects, though. I'd built a mechanism that I planned to work by hand during the shot so that the eyes could roll back and then disappear into the skull and there'd just be empty sockets there. But with the motion control, it would have meant building an additional rig for that; and at that point I was very, very tired and it just didn't get done. The melting effect itself was done with two large forced-air heaters mounted at forty-five-degree angles off either side; and I stood by with a hand heat gun to make sure the melting went evenly. I guess it took about ten minutes, or maybe more, for the thing to actually melt down to where they wanted it. It was shot motion control time-lapse with a fairly wide-open shutter to get the blur on it, and it ran about twelve or fifteen seconds — which was closer than



Pyrotechnics expert Thaine Morris engineered the pillar of fire using smokeless gunpowder fired from mortars. Miniature Nazis are caught up in the burst.



Model maker Paul Huston prepared a miniature rendering of the canyon set, with scaled-down Nazis and props, which were used for the firestorm shots. During

the original ten or fifteen minutes, but still not a hundred frames. It was finally brought down to the length it is in the film by step-framing it.”

photography, the set was positioned upside down so the flame directed at it would cling to the surface. Richard Edlund and stage technician Dick Dodd wait as the miniature submarine slowly moves into position. The real island in the background was replaced with a matte painting in the final composite.

Colonel Dietrich’s shrinking head was Walas’ personal favorite. “We put probably the most work into developing that head and all its different capabilities; but unfortunately, you only see about ten percent of it in the film, which disappointed me no end. The final one we ended up with had the face shriveling down, the eyes rolling back, bleeding from the mouth and ears, and mucous dribbling from the eyes. We also had an actor’s hand in there grabbing and then dropping out of the frame, and Stuart Ziff had built a mechanism for it so that the head could rock and roll around as it was happening. I hooked the jaw up, too, so it was opening and closing, and then we had the whole head sort of dropping out of the frame at the same time. We did a couple tests, but George didn’t like it. He wanted it to look more like a mummy, and have it just get very rigid. In order to facilitate that, we had to take the whole thing apart and remove the mechanism. Later we came up with another idea of painting the outer surfaces as skin and having the underlying bladder painted as a rotting sort of corpse thing. Then, as the face began to shrink up, the skin would flake off and reveal the rotting flesh underneath. We did a couple of tests of that, too, and I thought we were really getting somewhere. But George didn’t seem to like that, either.

“Making the bladders was the most difficult part, because when they were inflated they had to look like a real face. If it was too thin, it wouldn’t maintain the proper shape; if it was too thick, it wouldn’t fold down properly. And you had to do it without getting a lot of irregularities. Wesley wound up doing most of the work on those, and he must have made twenty or thirty of them just trying to get one that was workable. We also had to resculpt the skull with giant grooves and wrinkles in it so that as the skin drew down it would go into all the little nooks and crannies and give it more of a mummy look. Stuart Ziff made up a little pressure-gauging rig which would maintain the exact pressure and vacuum levels inside, so that was a lifesaver; and Gary Platek helped a lot in getting the vacuum pump rigged up. We had quite a lot of trouble controlling the fluids running through the head, because all these lines had to be run literally through a vacuum, which would either slow it down or speed it up. We did tests where nothing at all would happen until it got to a specific threshold — and then blood would come flying out of the ears two feet. It looked like somebody was in there with a squirt gun. The blood tubes and the goo tubes and all that stuff had to be really sealed in tightly, too, because the vacuum was very strong and it tended to pop the seals. We’d do takes where we’d be pumping blood like mad, and we could see it going in, but nothing coming out. So we’d pop open the bladder a little bit and we’d get this flood of blood, because the line itself had split. Fortunately, we could usually rerig everything in about an hour, so we were able to get off four or five takes in a day. It took a lot of finagling, but we finally got it.”

From there, things go from bad to worse for the Nazi defilers as awesome firebolts emanate from the Ark, piercing the attendant troops in a lightning-like chain reaction. For the most part, the local actors hired principally for the end sequence insert shooting had spent their days trying to react convincingly to an invisible array of swirling apparitions; but for the firebolt shots they actually got to do something, since interactive lighting on the live-action plate was required to correlate with the primary effect which would be accomplished later in the animation department.

“Ultimately,” said Edlund, “we were going to animate the bolts coming from the Ark and striking these guys, shooting out their eyes and going through them, and then jogging over and going through the next guy. Of course, it was all going to be happening real fast, and I suppose we could have just shot a bunch of guys flailing their arms and then done the rest with animation; but I thought we needed to get some light inside their clothing to really carry it through. So we made up a bunch of harnesses, each of which had an extremely bright projection bulb in the front and an enormous flashbulb in the back. We dressed our Nazis up with these things under their uniforms; and we had to position them very carefully, otherwise they looked like hunchbacks with these big bulges sticking out. They all had switches coming down into their hands so that when they saw the flashbulb go on the guy directly in front of them they could hit their own switch and you’d get kind of a ripple effect. The flashbulbs were so bright it looked like two tiny suns inside their shirts; and they lasted for about two seconds, which was just about the right amount of time. Then the lights kind of made the guys’ faces glow and the bulbs would smoke a little bit and you’d get all these extra little throwaway touches that you’d never be able to get with animation, even if you thought of them.”

“During the summer before we really got into *Raiders*,” Sam Comstock recalled, “we had a little time to develop the look of a number of the effects, and so I had several different people in the department draw their notions of what the bolts should look like — just quick pencil tests — and I did one, too. We deliberately tried for something that was fiery, but which also had sort of a raw energy violence to it and a little electrical quality to make it more logical to have this long arcing thing stretch out over such a long distance. The final look, as it turned out, was pretty much selected from the concepts that I came up with; but since most of my time went into supervising, Kim Knowlton, Loring Doyle and Scott Caple did the actual animation — and they worked real hard to get just the right amount of violence and yet maintain a strange kind of energy look to it. We had a little trouble with some of the plates because we had to time our bolts to correspond with the actual flashes on the guys’ chests; and some of them didn’t go off at the best times, so we had to do some fudging here and there.”

The climactic pillar of fire which erupts from the Ark and pierces the heavens above was produced as a more or less straight pyrotechnic effect under the supervision of pyro expert Thaine Morris. A precursory scene, in which a raging firestorm sweeps over the cowering Nazis, was produced using a four- by five-foot replica of the full-scale set, built under the supervision of model shop foreman Lorne Peterson and outfitted with an assemblage of miniature human figures. “We mounted that miniature upside down,” said Richard Edlund, “so when we put the fire in there it would follow the contours of the surface. For the first shot, we put the camera upside down, too, and shot the flames coming down on the Nazis. The second shot, where the fire gets sucked back up inside, we also shot forward and then had to dupe for reverse action. That shot, I thought, worked pretty well, because

image

A vintage seaplane was located, but since it was on dry land and could neither float nor fly, the ILM crew built a platform next to it for the actors and photographed it as a matte element.

image

In the final composite, a separate live-action element was added of pier pilings and water, and the rest was painted by matte painting supervisor Alan Maley.

at that point everything was reduced to ashes. On the one with the Nazi dolls, though, I felt we should have gone back in there and painted little hobnails on all their boots and things like that, because the foreground guys, to me, looked pretty stiff and didn't have the fineness of detail I would have liked. But it seemed to work, nevertheless.

"The main idea for the pillar of fire was to come up with a pyro effect that didn't produce much smoke, and what we ended up using turned out to be so simple I'm almost ashamed of it. All it was was smokeless gunpowder — Green Dot smokeless powder. The stuff's great because it doesn't smoke and it doesn't have all kinds of sparkly embers that tend to make it impossible to get scale effects. We put it in mortars and then fired it up into the air. We did quite a lot of tests with various kinds of tubes and metallic things to form the fire and get it to behave the way we wanted it to — which was no easy task because it definitely had a mind of its own. The little hook, for example, at the top of the pillar, we got by firing it into a black metal scoop that was formed in such a way to make the fire flick around. Then we had the shot where the camera's looking down and the lid of the Ark comes flying up as the flame overtakes it. That was a devil of a shot because the thing was small — about the size of two cigarette packs — and we had to fire it straight up so it wouldn't flip around. Also, it had to just barely miss the lens because we were using a very wide lens and if it didn't get within two or three feet it would look like a tiny speck. So we had to do it with a little explosive charge, and it was a real tricky millisecond-timing type thing. But it was the only way we could have done it. If we'd tried to shoot the lid using motion control and then composite it with the flame, it would have been an impossible sandwich. All the fire was shot at three hundred sixty frames a second — in anamorphic format because there isn't a VistaVision camera available that can shoot that fast. So I had to build a little printer that would take three hundred sixty frames-a-second anamorphic material and blow it up to VistaVision flat so we could introduce it into our optical system. We considered at one point doing the flames with animation, but animated fire is real hard. If you look at *The Ten Commandments*, that's pretty good animated fire — but it still doesn't look like fire. The main problem is a perceptual one. If you look at separate frames of real fire, it has the strangest continuity. It doesn't seem to follow from frame to frame. Your natural tendency is to try and find order in it; but as an animator, if you do that, it just doesn't look right. The animation department did, however, do a lot of enhancement on our fire shots."

"On the first shot," Sam Comstock elaborated, "where the fire comes up out of the Ark, we did some mattes to help it fit and shape it a little better — which was real difficult to do with slow-motion, high-pressure flames that they wanted to start small and get large. So that was actually a matte — a soft-edge matte. Kim Knowlton worked on it, and she studied the character of the flickering edges and things like that so that when her matte stopped halfway through the shot, the fire would continue to move on in the same way. There were also some arms of fire extending out from the sides that had to be trimmed down as well. It was pretty tricky. Also, for the long shot of the island in the distance, Sylvia Keulen did a very nice growth matte to help the fire shoot up in the air. It was actually a continuous stream of fire, but she did a reveal matte with a charactered 'end' of fire as it grew up into the sky."

The long shots of the island, where the pillar of fire shoots up into the clouds and then recedes back into the Ark, were among the most complex optical composites in the film. The island itself was a matte painting, painted over a water plate photographed in nearby Richardson Bay. (An earlier shot

of the Nazi submarine approaching the island base employed a refurbished twenty-six-foot Japanese sub constructed by Greg Jein's miniature unit for 1941.) The flame footage, photographed in anamorphic format, had to be converted to VistaVision and then combined with the articulate roto mattes prepared by the animation department. Even the clouds overhead were artificially generated in a large water tank by Gary Platek and Don Dow.

As it turned out, the water tank — which was also used for shooting most of the ghost footage — was to receive a major workout on *Raiders of the Lost Ark*. Constructed originally for the cloud effects in *Close Encounters of the Third Kind*, the large inch-thick glass tank — seven-foot square and four feet deep — was refitted by ILM primarily to produce controllable “weather” conditions for the end of the picture and for the earlier Well of Souls sequence in which Indiana Jones and his cohorts labor feverishly to excavate the entombed Ark while a churning thunderstorm rages behind them.

“Using the tank, we were able to do two cloud shots a day,” explained Gary Platek. “We’d start by putting in a layer of salt water — about a foot-and-a-half’s worth. After that, we’d put a piece of polyethylene sheet plastic on top of it and add a layer of fresh water. Then we’d slide the plastic out and let the water settle for a couple hours. Since salt water is about one-and-a-half times denser than fresh water, it would stay on the bottom. The fresh water would stay on the top, and then there’d be a kind of vague layer you couldn’t even see where it was sort of both. That seemed to be the best place to get most of our cloud effects.”

From behind the camera, Platek was able to create his clouds by injecting bursts of Tempa white paint into the inversion layer using a manually operated, remotely-controllable pneumatic arm similar to those employed in handling radioactive isotopes and other hazardous materials. Different-shaped probes, painted black, were used to generate different types of clouds. “We had point sources,” Platek continued, “and bars and hoops with different size holes and different pressures. In the beginning, the Well of Souls shot was supposed to have rolling thunderclouds coming from the distance up to the camera. We used a giant ‘T’ probe for that — about three feet across — and I’d lay the clouds right into the nebulous area between the two water layers, as close to the salt as possible because that limited the height of the clouds. Then, as it came forward, I kept raising the probe up and up so the clouds would get bigger and bigger and force the perspective. Getting the right perspective was really about the most important thing. If the camera’s point of view was correct, the clouds would fit into the scene very nicely. Shooting was a pain though. We used an original Mitchell VistaVision camera with two-thousand-foot loads and it weighed a ton, so we would usually try to get one camera angle and leave it at that. Then, since the camera was so large and the tank was so low, we’d have to squat on the ground and look up to see our shots.” Only



For the required flying shots, Mike Fulmer produced a scale replica of the seaplane, which was photographed by effects cameraman Jim Veilleux using bluescreen and motion control techniques.

image

The inflight composite would later serve as background for an animated map delineating the aircraft's route.

two shots a day were possible because of the time required to fill the tank and let the layers settle out. The water was pumped in from two adjacent thousand-gallon holding tanks — one for salt water and one for fresh — that were filled at the end of each day's work so they could filter overnight and be ready the next morning. "We filmed in a darkened room so that the water would essentially expose as black, and we'd try to adjust our exposures so that any extraneous stuff in the water would drop out. That way we didn't have to go nuts trying to get Sparkletts-type clearness. Some of the shots, though, were actually helped out by having a little bit of something in the water. It'd make a bit of an atmosphere and give the shot more depth. But you wouldn't want to get carried away with it. In the beginning, we had a real problem getting clean salt. Most of it was used for tanning or something, and whenever we dumped it into our tank we'd end up with muck because the salt was so dirty. Finally, we found a company that would sell us rock salt, but we had to buy it in three-ton lots. We had a fire hydrant out at the corner of the building and the fire department loaned us hose so we could fill our tanks. Then Don Dow and I had to physically lift this salt and dump it in. We ended up going through nine tons of it on *Raiders*."

One of the more mystifying cloud effects was used in the film's finale. As the pillar of fire forms over the Ark, a circular opening appears in the cloud layer above and the fiery column shoots up through it. Gary Platek produced the effect merely by jumping on the flexible drain hose that ran out of the bottom of the tank, sending a burst of water up through the stratified water layers, in turn forcing the paint cloud to iris open and then roll back together and subside. Even the simplest of techniques, however, required considerable experimentation and refinement; and with all the random factors involved, the cloud photography kept Platek and Dow occupied for a full six months. "We had *miles* of cloud footage, but we were always getting new things. Every day, after we'd shoot, I'd try out a new probe or a new paint mix or something — and soon I learned to shoot film every time we did something, because sometimes we'd get a fluke. In the Well of Souls sequence, the opening shot is sort of a bubbling ring that kind of dissipates and from then on it's just storm clouds. Well, the bubbling ring was a total fluke — we were never able to do it again."

Since lightning bolts were to be added to the storm sequence, the two cloud technicians devised a means of adding interactive lighting effects as they were shooting. "Those were our lightning guns," Platek explained. "They were pretty simple — just a single lens to focus the light — and we had about fifteen of them hooked up all around, above and below the cloud layers, and they would project spots of light into the tank. For light sources we used SX-70 flashbulbs, and we wired them up randomly to a nailboard. I'd be working the atomic arm, and Don would start the camera and then run over and start running the nail along the contacts. Sometimes one would go; sometimes five would go in sequence. It was a pretty good effect, but I think on most of the shots the animation department ended up putting in their own glows because the parts of the cloud that looked best for their purposes didn't necessarily hook up with our lighting effects."

Less obvious, perhaps, than a lot of the most flamboyant effects in the film, was the work done by the matte department, organized under the supervision of Alan Maley. Maley, an accomplished matte artist and Oscar-winner for his work on *Bed-knobs and Broomsticks*, had collected numerous credits in his native England (on such high-caliber films as *Dr. Strangelove* and *Becket*) before moving to Hollywood where he supervised the Disney matte department for about ten years. At ILM his supervisory "mentor" status involved not only the training of matte painters Michael Pangrazio and

Chris Evans, but also his personal brush talent on many of the numerous paintings produced for both *Raiders of the Lost Ark* and *Dragonslayer*.

For the most part, ILM matte paintings are done on glass, with the areas to be filled with live-action photography left clear. Completed paintings are then positioned in front of a Scotchlite screen and the live-action elements inserted via front projection. The basic front projection technique is one that Maley pioneered on *The Spy Who Loved Me*, though its current application has been enhanced immeasurably with ILM's motion control technology which allows for multiple-pass camera moves. "From my point of view," Maley explained, "the main advantage of front projection is that it allows you to do a shot very quickly. Plus you have a great deal of flexibility. You can zoom toward the painting without any change in brightness on the front-projected image; you can pan, as long as you're on the nodal point; and you can tilt — so there are quite a lot of moves you can make."

We can turn things around real quickly with front projection," matte cameraman Neil Krepela elaborated. "I can shoot a wedge in fifteen or twenty minutes, get it to the lab, see it the next day, and then the artists can work on it, shoot it again, and so on — so it's real quick. If, on the other hand, it has to go through optical, what they'll generally do is take the film that I've shot of the painting and either make an interpositive or separations from it — depending on how they're going to go with it — and it's usually a minimum of a week by the time we see it again. Sometimes we'll use rear projection, which allows you to track in and out of the painting, but since you're using ground glass or a Stewart screen or something like that, you wind up with kind of a diffused image rather than a focused image — so front projection's got a little better quality. With rear projection, too, you generally have to do longer exposures."

Although many of the painting shots were fully composited in the matte department, some required a complexity of other elements to achieve the desired illusion. For the seemingly simple bottom-of-the-pit shot in the film's opening sequence, cameraman Jim Veilleux photographed individual bluescreen elements for each of the rocks that came tumbling down toward the camera as Indy scrambles to escape. "It was crazy," Richard Edlund remarked. "You'd be sitting there in dailies looking at this giant blue screen with all these flags and gobo stands and wires and pylons sticking out into it, and here'd be this little rock that comprises about one percent of the screen area."

Other shots were considerably more complex.

"George had an idea that he wanted to have a *China Clipper* in the film," said Edlund. "So we found a really excellent model of one in an air museum in Modesto, and we went out and took pictures of it with the idea of building a model and having it fly around. In the meantime, however, we turned up an actual full-size flying boat not far from here. It wasn't in the water and it wouldn't fly, but they were able to start up one engine. So we went out there and we put some shallow pools of water under the wings to reflect the sunlight up, and we built a ramp for everyone to walk along, and we did the shot with

image

Matte painter Mike Pangrazio adds finishing touches to his painting of the Raven Saloon in Nepal.

image

Alan Maley at work on the cliff painting. Since the required camera move — an extended tilt-down — would have been impossible for the matte camera, the painting was rendered sideways in forced perspective so that the camera could be mounted on its side and simply panned.

image

Indy and the others boarding the plane — all on dry land. In fact, a lot of the people who were in that sequence were people from the studio here. Dennis Muren got dressed up like a spy and it was he who's looking out over the *Life* magazine. Later I went up in

The film's closing scene. Aside from a small section of corridor and a few genuine crates at the point where the warehouseman turns down a side aisle, the entire frame is a Pangrazio matte painting.

a helicopter and scouted the Bay Area for a pier that we'd be able to use. I found one on Treasure Island, so Jim Veilleux went over and photographed it with the exact same camera and lens and angle, and then Alan painted in the rest. So the flying boat is real and the pier pilings are real, but the top of the pier and the yellow cabs and the buildings behind and the sky are all painted in. Even the reflections in the water and the PanAm logo on the plane were painted." Subsequent flying shots, photographed by Jim Veilleux, were done with a miniature replica of the aircraft built by Mike Fulmer. One, a shot of it flying out over the Golden Gate Bridge, required Veilleux to employ a matched move technique — carefully plotting random moves on the background plate (shot from a helicopter by Richard Edlund) and then programming his motion control camera to follow them.

The gasp-producing shot where the Nazi jeep goes over the cliff was also an augmented matte painting. The live-action plate, filmed in Tunisia, had the vehicle running off the road and over a slight drop. At that point, it was replaced by a miniature jeep, complete with a driver and two passengers who tumble out of the vehicle as it plummets into the precipice. The jeep and its riders were stop-motion animated against bluescreen — one element at a time — by Tom St. Amand, and photographed once again by Jim Veilleux using motion control to impart their movement through the frame. The cliff painting, which had to be done in forced perspective to suggest great depth, was painstakingly rendered by Alan Maley, and tested over a period of several weeks. Since the required camera movement — an extended tilt-down — would have been impossible to achieve with the matte camera, Maley prepared his eight- by four-foot painting horizontally rather than vertically so that the camera could be mounted on its side and panned across the surface to produce the same result. The technique was not without its problems, however, since the rear projector used for the plate element also had to be mounted on its side, causing the lamp to produce unrepeatable and unpredictable levels of illumination.

The final scene in the picture — reminiscent of the closing moments in *Citizen Kane* — was an exquisitely rendered matte painting by Mike Pangrazio. The Ark, firmly encased and stenciled with stern warnings, is wheeled into a government storage facility as the camera draws back and back to reveal a hangar-sized warehouse crammed to the rafters with near-identical crates — untold thousands of potential Rosebuds, each perhaps with as interesting a story behind it. "That shot was difficult from a matte painting point of view," said Alan Maley, "because even though the painting is six feet long, when we start out on it we're actually focusing on an area that's maybe eighteen inches wide and about six inches high. Plus, even when the camera's drawn all the way back, the shot is still held *much* longer than one usually likes on a matte painting. So Mike had to paint to a much higher degree of detail on that shot than on any of the others." Aside from the narrow central corridor and a couple of genuine crates positioned at the point where the warehouseman turns down a side aisle, the entire closing shot — moody and atmospheric — was totally painted.

"I think what characterized *Raiders*," Richard Edlund concluded, "the effects as well as the whole picture, was a kind of shoot-from-the-hip approach rather than the high technology of *Star Wars*

and *Empire*. There were still some real tricky technical shots, but in general, we were freer and more easy about things. With a film like *Raiders*, you're trying to fool a very sophisticated audience. In fact, it's getting tougher every day just to fool your average ten-year-old. The people who work here always give their all to every shot, but you're still up against the wall and limited by time, so you never seem to finish a shot that you didn't think you could do better. A few of the shots in *Raiders* I would have liked to have seen a little bit longer. But I'm not about to argue with George's cutting, because he *really* knows how to use effects. He worked with us all the way through, and he personally supervised the editing of that end sequence. If you have a weak effect — and frankly, there are several in there that I feel are just borderline — you have to know how to use just the right amount of it, in the right circumstances, and put it between other shots that are stronger and make the whole thing work. And George can really do that. He'll take all the shots and sit back and put together this great big special effects Dagwood sandwich that everybody can get their mouth around."

Considering the success of the effects-laden *Star Wars* series and the vast fingertip resources of Industrial Light and Magic, it is a tribute to both Lucas and Spielberg that *Raiders of the Lost Ark* represents one of the more remarkable uses of special effects to advance rather than dominate a story. Not surprisingly, two other Indiana Jones adventures are already on the drawing boards — the next reportedly set in the jungles of Africa. Though characteristically tight-lipped on the subject, George Lucas has indicated that future films in the series will be less action-oriented and more involved with the occult. Should this prove to be the case, it is likely that the cinemagicians at ILM will have ample opportunity to exploit even further the ever-expanding bounds of cinematic illusion.

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